WESTERN UNION Technical Review

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Keyboard Standardization

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T. B. GITTINGS
VICE PRESIDENT

TO READERS OF

TECHNICAL REVIEW

A Happy and Prosperous New Year to you and your families!

As 1956 begins, it is appropriate to take a look at "the record" and at the future. Your company, "The New Western Union," has made amazing advances during recent years. These progressive improvements are of major importance to my department since all marketing, advertising, and public relations activities must rest on the firm foundation of good service attracting public appeal and use. Thus, it is largely through engineering efforts that Western Union people have been able to establish an outstanding record of achievement.

"Technical Review" has done much to keep all of us abreast of developments that have taken the company so far along the path of success. I am confident it has given you – as it has me – broadened understanding and justified pride in recent achievements and confidence in the future.

Today, as I look at the huge communications potential inherent in the development and growth of integrated data transmission techniques, I see new challenges and even greater achievements ahead for our research people. With this whole new field of automation opening up, and with the ever-broadening application of facsimile, there are no boundaries to our continued progress in the years ahead.

T B Gittings

Vice President – Public Relations
and Revenue Requirements

January 1, 1956.

W. DALE CANNON, Assistant to Radio—Wire Transmission Engineer

An Envelope Delay Measuring Instrument In The Audio-Frequency Range

It has long been recognized that careful attention must be given to the amplitude response of all types of communication systems throughout the useful frequency range. Other effects arising from system phase characteristics became evident as circuit lengths increased. These effects, resulting from phase distortion, persisted even after perfect correction had been made for amplitude distortion. In telephony for relatively short distances, phase distortion was usually of small importance. However, with the increased length of circuits phase distortion over the essential range of frequencies was found to play an important role. In landline code telegraphy, d-c or carrier, the effects of phase response are negligible compared with amplitude response. In any event the processes of signal regeneration, sampling or pickup, and code translation, provide a "margin" within which distortion effects are absent and a perfect printed reproduction of the telegraph message is obtained.

With the advent of facsimile, telephotography and television, it was soon apparent that these systems, lacking the compensatory factors present in code telegraphy and telephony, require careful consideration of phase relations as well as amplitude response. Thus, in facsimile transmission the signals are largely transient in nature, and for faithful reproduction in the received copy the waveshape of the transients must be preserved or restored to the original form prior to recording.

It is usual to predict the transient response of a circuit from the steady-state amplitude and phase responses. The transient response is uniquely related to these responses by the Fourier Integral Equation or similar forms. Relations of this type do not lead to a simple means of measuring the important transmission factors. It is, therefore, desirable to have available a more practical means of determining these factors from the steady-state properties of the circuit.

The steady-state amplitude response of a circuit may be measured and corrected to a uniform value by simple means. The situation with regard to the phase response is a much more difficult matter and involves not only a number of phase related properties which may be measured but also a relatively complicated means of correction. The question, therefore, arises as to what phase related parameters or properties to measure particularly for corrective purposes. The subject matter of this paper includes consideration of this question and description of a new instrument for measuring envelope delay in the audio-frequency range.

Phase Related Parameters

In the transmission of periodic waves through a medium, the amplitude and phase responses are usually considered in terms of the steady-state parameters α and β so that the propagation constant is $\alpha+j\beta$. Since periodic pulses may be represented by a constant along with a number of harmonically related sine and cosine waves having different amplitudes, the shape of the pulses will be preserved in transmission if all the components are transmitted with the same velocity at a uniform attenuation α of the circuit. For periodic waves the condition for transmission without phase distortion is that $\beta=\omega T+m\pi$ where T is the time delay interval in transmission and m is an integer. If m is not an integer, a form of distortion is present known as linear-phase intercept distortion.

If, instead of periodic waves, two sinusoidal waves of slightly different frequencies are considered as being prop-

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agated through a medium, it can be shown that the conditions for distortionless transmission are somewhat different. These two waves will travel through a medium having phase distortion at different velocities and will form crests and troughs which will travel at a slightly different velocity from the component waves. It can be shown that the crests thus formed are delayed by the factor $d\beta/d\omega$ commonly referred to as the group or envelope delay; whereas the component waves are delayed by β/ω. For a distortionless medium, the envelope delay and the phase delay become equal.

Likewise, this procedure can be extended to three frequencies of an amplitude or frequency modulated wave comprising a carrier and two side frequencies, in which case the modulation is delayed by $d\beta/d\omega$. However, an effect due to phase distortion occurs, which is not present for two frequencies, similar to intercept distortion for periodic waves in that for particular phase shifts which are not zero or multiples of π, the original modulation will be destroyed and replaced principally by a second harmonic of the original modulation.

The foregoing is applicable to steady-state conditions and applies to signals or wave trains that for practical purposes occupy a period of time long enough that all transient effects have disappeared. A study of finite wave trains rather than infinite wave trains runs into considerable difficulty even for the most practical simplifying assumptions. The transmission of a few types of finite wave trains has been studied by J. R. Carson[1] and S. P. Meade.[2] Here, not only the first derivative $d\beta/d\omega$ but also higher order derivatives are of importance.

Hence with respect to delay distortion in transmission circuits, the most important factor to be considered in general is envelope delay $d\beta/d\omega$, and it is not necessary to consider phase shift directly as such. Further in a distortionless system, the phase delay β/ω and the envelop delay $d\beta/d\omega$ are equal and constant throughout the useful frequency range and the second derivative $d^2\beta/d\omega^2$ is zero. Since the ideal system is generally not available in practice, the phase delay and the envelope delay will not be equal and the second derivative will not be zero. Fortunately, however, when satisfactory correction has been made for envelope delay distortion, it will usually be found that the phase delay also is within tolerable limits unless some use is to be made of the phase of the individual carrier cycles under the modulation. In this case β/ω should conform to some prescribed tolerance depending upon the actual application, particularly in regard to linear-phase intercept distortion.

Methods of Measuring Envelope Delay

It is evident that the use of steady-state conditions for the measurement of envelope delay in audio-frequency circuits has practical advantages both in simplicity of techniques and instrumentation, whereas measurements as a function of some quantity related to the transient state appear to be confronted with difficulties, particularly because of the connecting integral relationships. A number of methods of measuring envelope delay in terms of steady-state conditions are available, some of which give the result indirectly and others in the form of a characteristic curve. Indirect methods of measurement usually do not require elaborate equipment, but do require that the results be derived from the measurements, resulting in a somewhat complicated procedure. One procedure which may be used is the direct measurement of the phase shift itself which may be obtained by a number of methods. The resulting curve may then be differentiated with respect to frequency, to yield the envelope delay. Another method of measurement is by means of a single frequency which is varied in small steps or increments such that the incremental change $\Delta\omega$ can be considered essentially as $d\omega$. The corresponding $\Delta\beta$ is obtained by measuring the change in phase angle on a phase meter or similar device. The delay curves then are $\Delta\beta/\Delta\omega$ which are essentially equivalent to $d\beta/d\omega$ as obtained by a point-to-point method.

The methods discussed above are in general not very practicable for incorporation in an instrument for continuous

measurements of delay, particularly when it is desired to display the result as a plot of delay versus frequency. None of these methods are practicable for measurements on transmission systems in which voice-frequency circuits are derived by a modulation process requiring translation from one frequency band to another frequency band, since the received frequency in such voice-frequency circuits may differ by a number of cycles from the transmitted frequency. Another disadvantage arises when the two ends of the system are isolated from each other. This situation requires matched frequencies at the two ends of the circuit, which in many cases would be impractical, or another circuit to convey information from one end to the other. Another disadvantage of these methods is the time-consuming point-by-point process usually required.

Figure 1

Unit 1 (top) Regulated power supply and sweep oscillator
Unit 2 (bottom) Transmitter and receiver

A more practicable method by which the result is obtained directly is available by using two sinusoidal waves of slightly different frequency, which as discussed previously yields envelope delay. The result is obtained by measuring the time relationship of the crests of the envelope thus formed with respect to a reference, as the two waves are swept through the frequency range. The two waves having a constant and small frequency difference can be obtained by a modulation process. The delay information then is obtained by measuring the time relationship of the envelope as recovered by a demodulation process at the receiving end with respect to the original modulating frequency at the transmitting end.

This method is practicable when both ends of the circuit are available at one point or when a separate circuit is available between two separate points, but is not very practicable for the usual voice-frequency circuit when the two ends of the circuit are in isolated localities. A more practicable method is available when three frequencies instead of two are transmitted; the third frequency, a carrier with respect to the other two frequencies, may be used to supply information to provide a sweep for displaying delay at the receiving end against the transmitted frequencies as received at the receiving end of the circuit. It is evident that these three frequencies as obtained by a modulation process will have phase coherence and will add to give crests which in general will travel at a different velocity than the

With this new instrument recently developed by the Western Union Telegraph Company's research organization, accurate corrections can be made on telecommunication circuits for amplitude distortion and delay distortion in the audio-frequency range in a matter of minutes rather than hours or days as formerly.

Intended primarily for use in the choice or adjustment of corrective networks for equalizing delay and amplitude characteristics of facsimile and telephotograph circuits, the new instrument is equally valuable for rapid correction of high-speed data transmission circuits. Measurements may be made over a frequency range from 200 to approximately 12,000 cycles per second.

The device operates basically by comparing the time relationship of two sets of pulses, one set derived from an accurate tuning fork standard oscillator and the other from the 25-cps envelope of a modulated wave that has been transmitted through the circuit whose characteristics are being studied. The instrument is unique in that each measurement is completed in such a brief time interval that synchronism between sending and receiving pulses is not necessary. By continuously sweeping the carrier over the useful frequency range and measuring the frequency of the carrier at the receiving end, a plot of relative delay or of amplitude versus frequency is immediately and continuously available.

component waves due to delay distortion, thus yielding envelope delay. It also can be shown that either amplitude modulation or frequency modulation can be used to derive the three frequencies and will yield the desired result. However, since frequency modulation appears to be more difficult for instrumentation at the low carrier and modulation frequencies involved, and since signals to be transmitted such as facsimile signals are generally amplitude modulated, the amplitude-modulation method of deriving the three frequencies appears to be more practicable for use in a portable instrument.

The use of the amplitude-modulation method of deriving a carrier and two sideband frequencies avoids the shortcomings described above and permits the two ends of the circuit to be in isolated localities. The carrier at the transmitting end is modulated with a low-frequency test signal, such as 25 cycles, derived from a stable standard source. It is necessary only that this modulated wave be transmitted over the circuit and from it the desired information on delay and amplitude characteristics can be obtained. At the receiving end, the test signal is recovered from the modulated wave and is compared with a local standard on a relative time basis. If the relative time-indicating device has a linear response to this time relationship, then the standard sources at each end of the circuit need not be synchronized or phased with each other but may be allowed to drift slowly with respect to each other without limiting the ability of the device to indicate relative delay values. By continuously sweeping the carrier over the useful frequency range and measuring the frequency of the carrier at the receiving end, a plot of the delay information versus frequency is immediately and continuously available, which may be displayed on indicating meters or a cathode-ray oscilloscope.

Therefore, the three-frequency method will permit measurement of envelope delay characteristics and in addition amplitude characteristics versus frequency. It will permit immediate and continuous display of the information with respect to frequency, the frequency axis being obtained by measurement of the carrier frequency as it is swept through the desired frequency band. Absolute measurements of delay can be made when both ends of the circuit are available at the same location. Relative values can be measured when the two ends are in isolated localities. Carrier-derived circuits in which the received frequency may differ slightly from the transmitted frequency, as well as physical circuits, may be measured.

Operating Principles

The envelope delay measuring instrument embodies a practical application of the three-frequency method of delay measurements as derived by an amplitude-modulation process. It is a portable device suitable for the measurement of envelope delay and amplitude characteristics of circuits or equipment used for the

transmission of information in the audio-frequency range. It consists of two units as shown in Figure 1, each unit having over-all dimensions of 9½ by 9½ by 19¼ inches. Unit 1 consists of a regulated power supply and a sweep oscillator, and Unit 2 a transmitter and receiver. Since much of the circuitry is common to both transmission and reception, these two functions were combined in a single unit.

an instrument is required at each end of the circuit permitting relative delay and amplitude measurements to be made in either direction.

Three methods are available for displaying the delay and amplitude characteristics with respect to frequency: (1) by means of the four meters on the panel of Unit 2; (2) an external oscilloscope for which terminals are provided; and (3) ex-

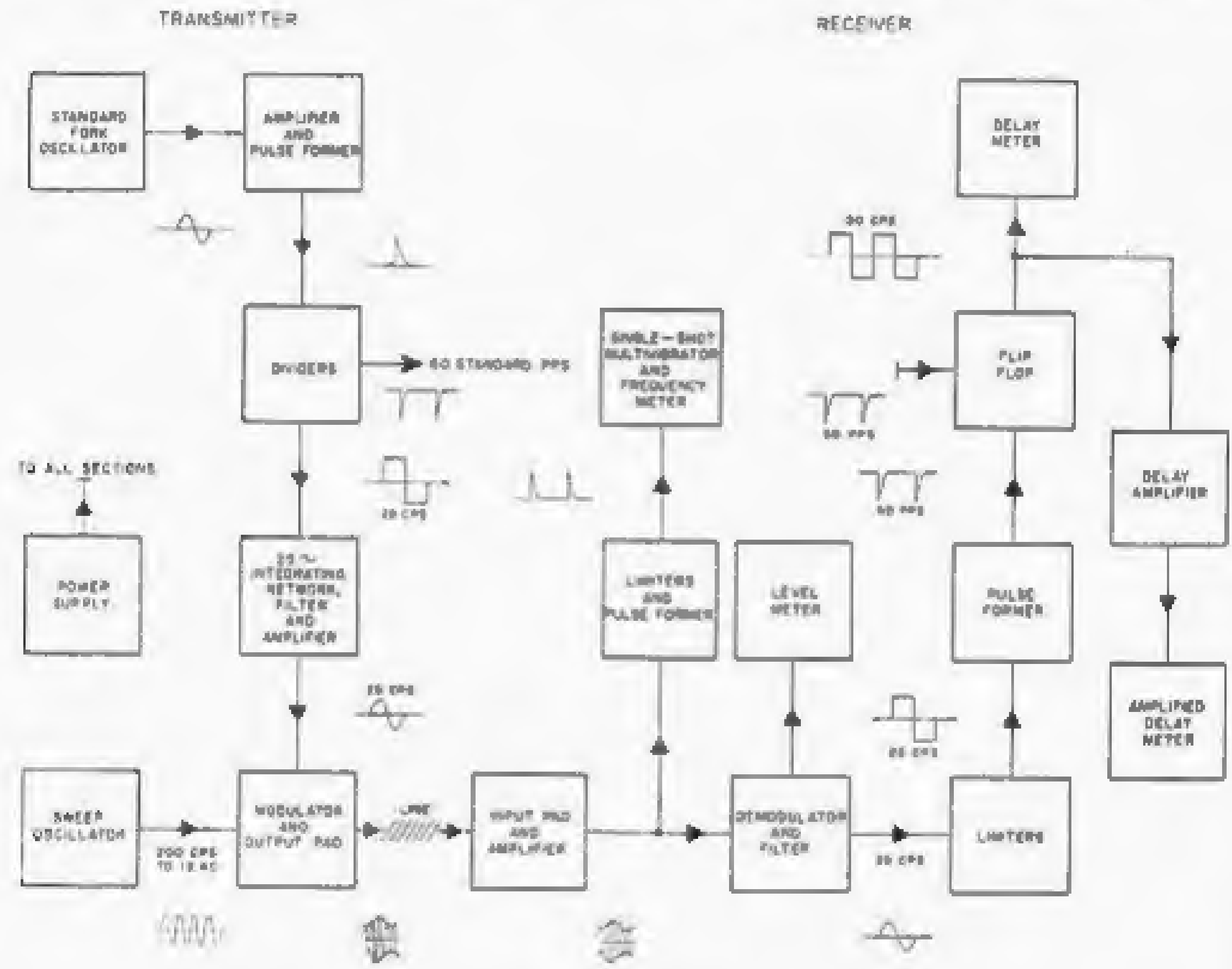


Figure 2. Block diagram

Measurements may be made over a frequency range from 200 to approximately 12,000 cycles per second. For loop measurements, only one instrument is required in which case both absolute and relative delay as well as amplitude measurements can be made. In this case, the output of the transmitter is simply passed through the circuit whose characteristics are to be obtained and thence to the input of the receiver. When the two ends of a circuit are in isolated localities, straight-away measurements are employed. In this case, ternal strip chart recording meters which may be inserted in any of the four meter circuits by means of the jacks provided. The delay and amplitude readings along with their associated frequencies appear on separate meters having delay scale ranges of 0-20, 0-5, and 0-1 milliseconds, and frequency scales of 0-3, 0-6, and 0-12 kilocycles. For indicated delay greater than 20 milliseconds, the instruments continue to function but the proper multiple of 20 milliseconds must be added to the readings as determined by other known

conditions of the circuit. The meter display is satisfactory for many purposes such as the indication of the flatness of delay and amplitude characteristics versus frequency in the application of corrective measures. Where permanent records of the characteristics are required, the meter display entails the almost simultaneous reading of two meters and recording the information while the frequency is being swept slowly, or provision for the frequency to be varied in steps at the transmitting end. In order to make the information more readily obtainable, a cathode-ray oscilloscope display method was adopted. The horizontal axis is connected to the frequency measuring circuit, and the vertical axis is connected to the delay or amplitude circuits. This arrangement makes immediately available a plot of relative delay or amplitude with respect to the sweep frequency being used at the transmitting end. This curve may be either photographed or traced and kept for permanent records.

The instrument operates basically by comparing the time relationship of two sets of pulses. One set is derived from an accurate tuning fork standard oscillator. The other set is derived from the 25-cps envelope of a modulated wave that has been transmitted through the circuit whose characteristics are to be obtained. The 25-cycle modulating frequency is derived by frequency division from the standard oscillator. The carrier is generated by a separate sweep oscillator, the frequency of which is adjusted to cover the frequency band of the circuit under observation. Thus the time position of the second set of pulses with respect to the standard set of pulses varies in accordance with the envelope delay of the circuit.

A block diagram of the instrument is shown in Figure 2. In loop measurements where one instrument is used as both transmitter and receiver, a single standard oscillator is the source of both standard and comparison pulses. The time relationship between these pulses then depends only upon the envelope of the modulated wave transmitted over the circuit being tested, which is a function of the carrier frequency, and the additional delay which results from the instrument circuitry. This latter delay remains essentially constant over the frequency range of the instrument and may be subtracted from the indicated value to yield absolute delay. In straight-away measurements where a separate instrument is used at the transmitting and receiving ends, two different standard oscillators are supplying the standard and comparison pulses respectively. Therefore, the time relationship between them depends not only upon the criteria stated for loop measurements, but also upon the phase relationship between the two standard oscillator output waves and upon the slight frequency difference which may exist between the two standard oscillators. Consequently, it is practical to make measurements on a relative basis only unless additional means are provided for phasing the standards at the two ends of the circuit. Since absolute values are very rarely required in straight-away measurements, it is not necessary to provide this means which is not easily accomplished. It is only necessary that the drift between the two standards be slow enough to permit time for the measurement to be made within the limits of allowable delay error. This drift can be made negligible for long periods of time by manual adjustment of the standard oscillator at the receiving end. Thus, slight differences between the standard frequencies at the two ends of the circuit do not incapacitate the instrument.

The circuitry of the instrument may be divided essentially into eight sections; the regulated power supply and sweep oscillator contained in Unit 1, Figure 1, and the standard oscillator, transmitter, receiver input, frequency indicating, clipping and pulse forming and delay indicating sections contained in Unit 2, Figure 1. The power supply is conventional in design for supplying the plate and heater potentials.

Sweep Oscillator

The sweep frequency oscillator is of the beat frequency type with two high-frequency oscillators operating at about 135 kilocycles. The output of each oscillator is

fed to separate cathode followers, the outputs of which are impressed upon the grids of a twin-triode grid bias modulator. A low-pass filter removes the carrier and high-frequency modulation products but permits the passage of the difference frequency. Since the two triodes operate in push-pull, even harmonics of the difference frequency are suppressed in the output when the modulator is properly balanced. The modulator output is applied to a twin-triode output stage which includes additional filtering. The sweep frequency then is a sine wave having harmonic content below —45 db.

Continuous sweeping of the frequency is performed by a variable air capacitor in the tuned circuit of one of the oscillators, while the frequency of the other remains fixed. The variable capacitor is mechanically driven by a synchronous motor so as to provide a constant repetition rate for display purposes. The sweep repetition rate is varied in four steps by means of a gear system which is controlled by a rotary lever on the front panel of Unit 1. This capacitor is in parallel with one of much larger value than itself and is so constructed that the spacing between the stator and rotor plates may be varied. This arrangement provides a means of varying the band of frequencies covered by the sweep range while maintaining a linear frequency sweep throughout the range. The other oscillator contains a variable capacitor in its tuned circuit which permits the setting of the sweep-band of frequencies at a particular position in the spectrum and also permits setting the sweep-band limits without a trial and error process.

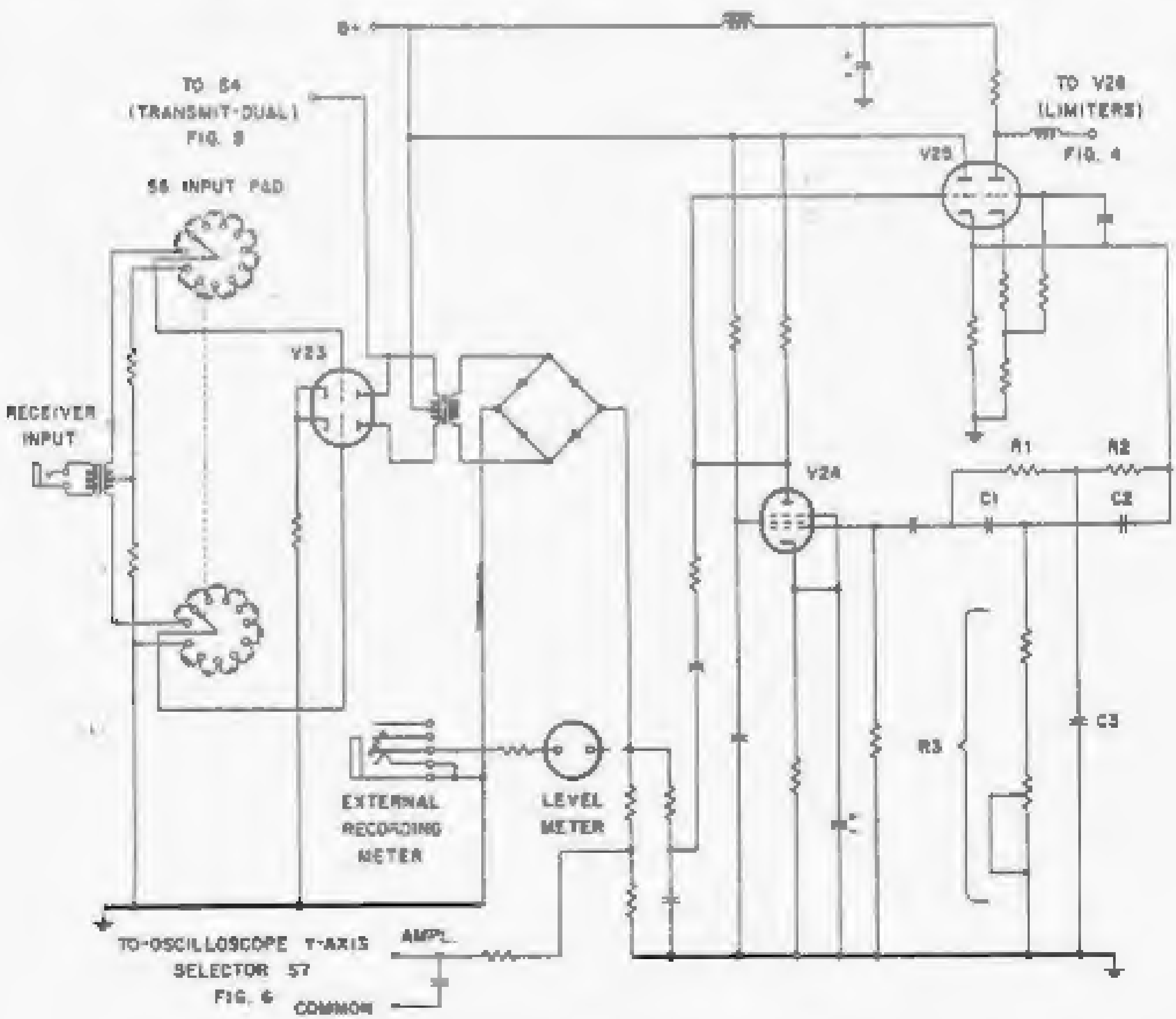


Figure 3. Input amplifier demodulator and filter

Standard Oscillator

The standard oscillator consists of a precision tuning fork unit and a twin-triode amplifier stage. The output of this stage is coupled through a small capacitor to a heavily biased Class B amplifier which acts to suppress the negative swings of the oscillator waves and produce steep positive pulses

Transmitter

The positive pulses from the standard oscillator section are used to control a series of cathode-driven frequency dividers which produce first negative pulses of very short duration having a repetition rate of 50 cps. The 50-cps pulses are used as the standard reference from which the delay indication is derived as discussed further in the delay indicating section. The final frequency division step is a binary stage which has a 25-cycle square wave output. After having been divided down to 25 cps, the square wave is integrated to produce a triangular waveshape which then may readily be converted to a pure sinusoidal waveshape by a tuned network and a push-pull amplifier

The 25-cps output from this amplifier and the sweep frequency from the sweep oscillator of Unit 1 are transformer coupled to a balanced modulator which suppresses the 25-cps modulating frequency in the output. This modulator is a double pentode grid-bias type using remote cut-off tubes with balanced transformer output accurately adjusted to 600 ohms. The output signal is approximately 50 percent amplitude modulated, having distortion components not in excess of —45 db with respect to the carrier level and practically constant level throughout the frequency band. The modulated signal is fed to the circuit to be tested through an adjustable output pad

Receiver Input

The receiver input section, Figure 3, is coupled to the line by a balanced transformer having an input impedance of 600 ohms. From the transformer the signal is amplified in a twin-triode push-pull stage from which the signal is used to drive the frequency indicating section as described in a following section. Also the output from the amplifier is used to drive a diode bridge demodulator, the output of which is first used to provide a source for the level meter, a voltage for oscilloscope display of input level versus frequency and also a source for use with a recording meter The demodulator output is next fed to an R-C filter where the carrier is partially removed. The signal is then impressed upon an active filter to obtain a 25-cps pure sine wave. This filter consists of a

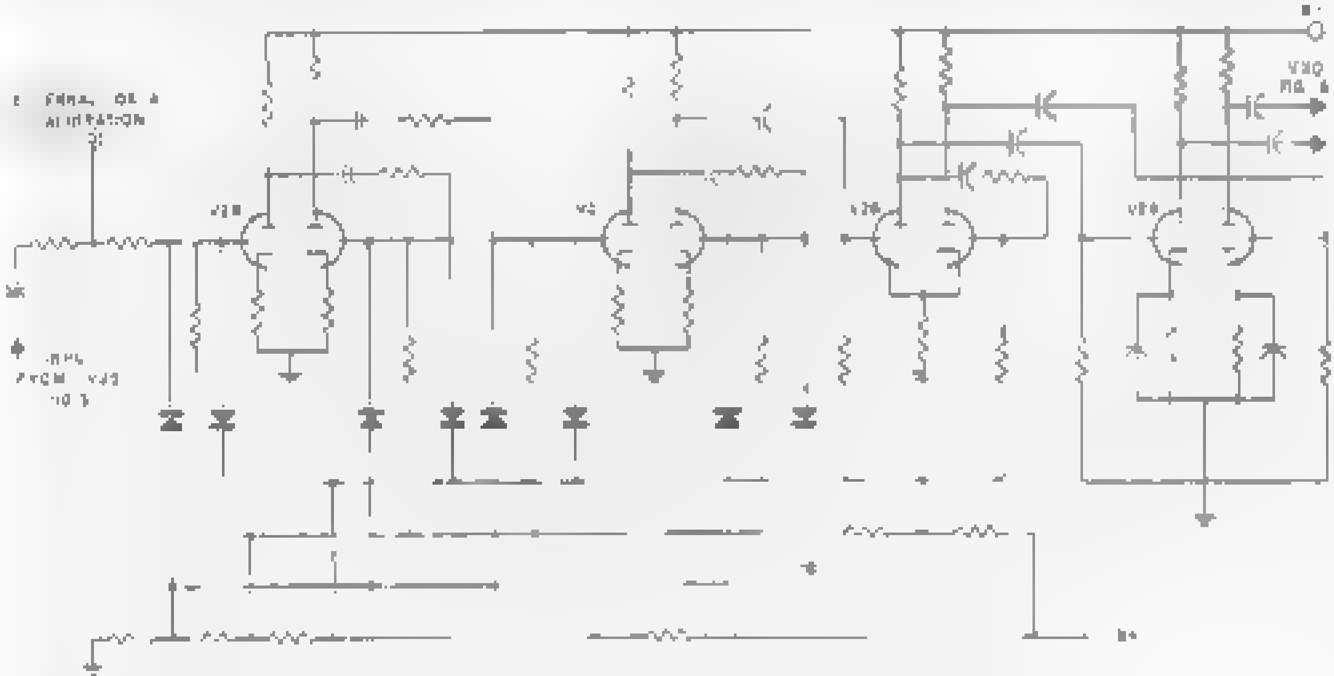


Figure 4 Limiters and pulse former

high-gain pentode amplifier, a cathode follower a parallel-T blocking network in a feedback path, and an output amplifier. This system not only removes the sweep frequencies, but also harmonics of 25 cycles, d-c variations, and any 60 cycles present. In addition, this system has a very important property in that unwanted delay variations due to rapid changes in signal level are opposite to the variations produced by the previous R-C filter. The parallel-T network can be adjusted by means of R_8 so that practically perfect cancellation results.

Limiter and Pulse Former

The recovered 25-cycle waves are fed to a series of four diode limiter stages as shown in Figure 4. The clipped waves are then fed to a stage of grid clipping after which the waves are differentiated and impressed on a Class B stage so that only negative pulses appear in the output from the plates and the positive pulses are partially suppressed. A double diode further removes the positive pulses and because of the phase relationship produces 50 negative pulses of very short duration from the original 25-cycle waves.

Frequency Indicating

The frequency indicating section may be used to measure the frequency of either the transmitted or received signal depending upon the manner in which the instrument is being used. The frequency of the amplified signal of the input section or the frequency of the sweep oscillator at the transmitting end is impressed upon four limiter stages, Figure 5, which produces a short pulse for each carrier cycle. These pulses are then used to trip a one-shot multivibrator once for each cycle of the carrier, the output of which is averaged in the meter circuit to give an accurate indication of transmitted or received frequency. In addition, a separate voltage proportional to frequency is derived from the plate circuit of the multivibrator for application to the X-axis of an oscilloscope to display delay or amplitude characteristics versus frequency.

Delay Indicating

The delay indicating section, Figure 6, employs a flip-flop circuit in which a negative pulse in one grid trips one plate on and the other off, and a negative pulse in the other grid trips the flip-flop tube in

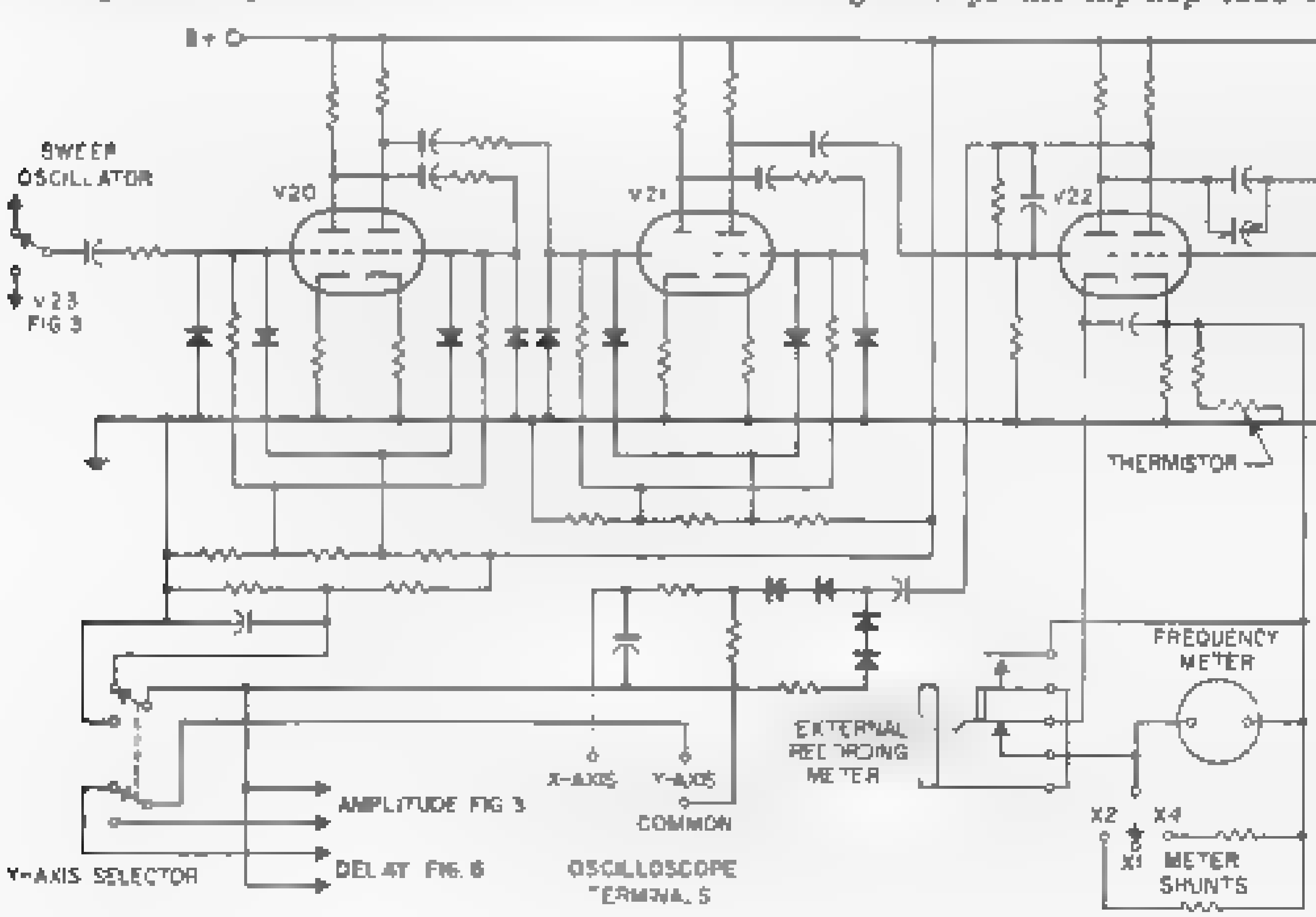


Figure 5. Frequency indicating section

the opposite direction so that only one-half of the tube may be on at any time. The tripping is done with two sets of negative pulses at a 50-cycle rate, one set being applied to each grid. The standard set is derived from the 50-cycle divider stage as described previously. The other set is derived from the recovered 25-cycle waves in the clipping and pulse forming section. Since both sets of pulses are of the same repetition rate, the average current in each half of the flip-flop tube depends upon the time relationship of the two sets of pulses. A measure of the average current difference between the two halves of the tubes is then an indication of envelope delay of the circuit being tested. An additional delay results from the passage of signal currents through the circuits of the instrument. This delay, however, remains practically constant with frequency and may be subtracted from the indicated values when absolute values are required in the case of loop measurements.

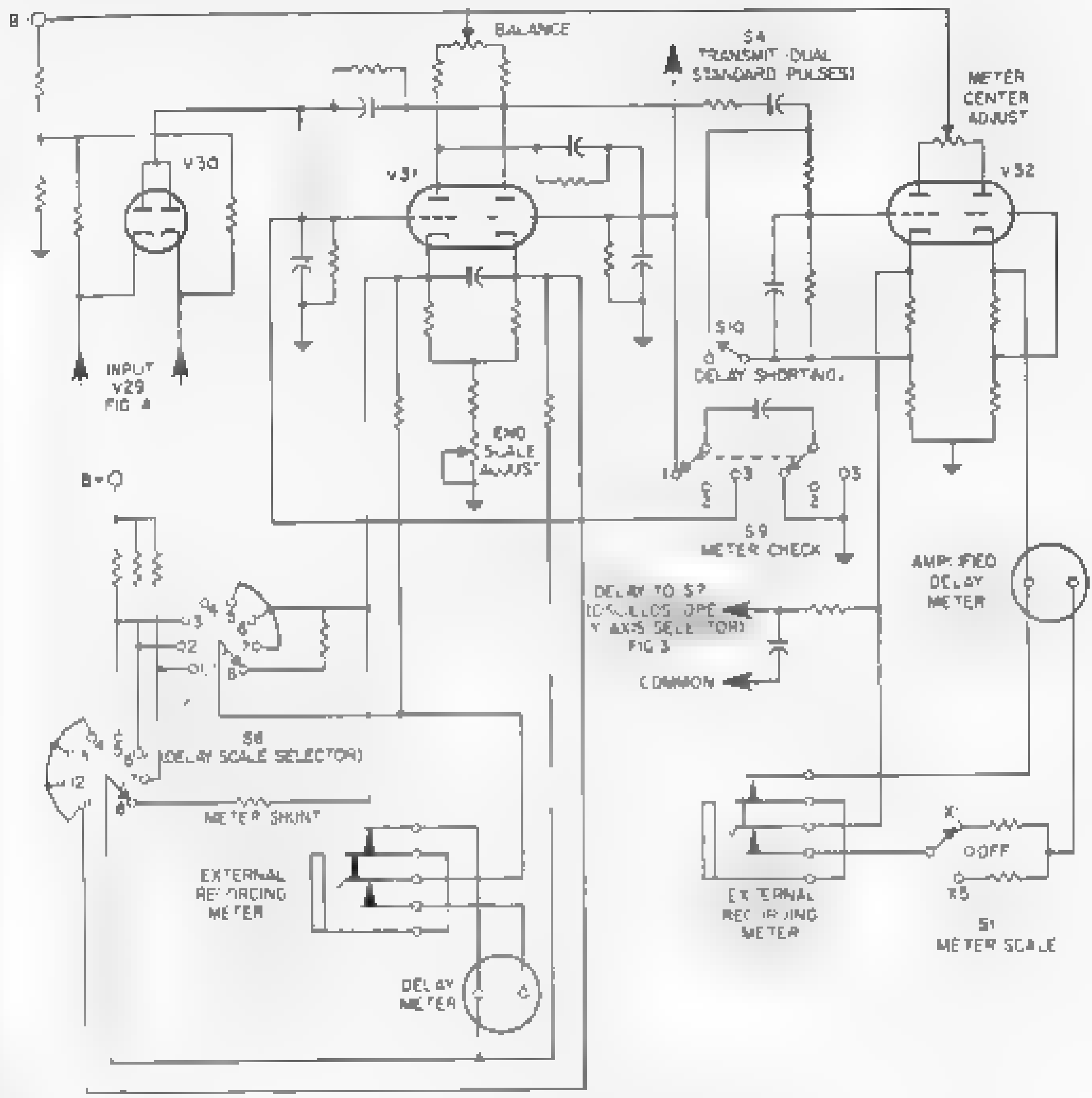


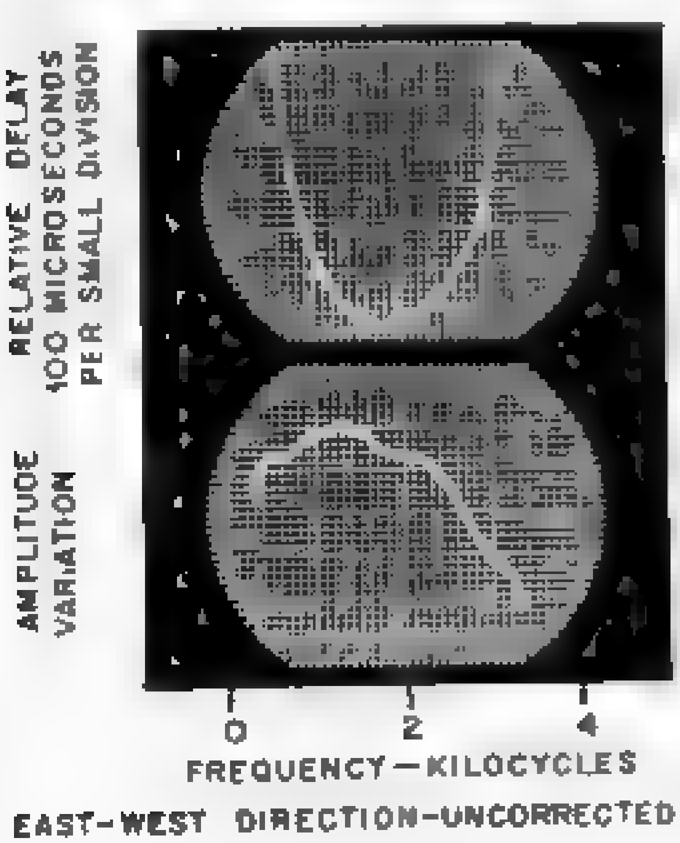
Figure 6. Delay indicating circuits

A d-c meter is bridged between the cathodes to measure average current differences. Since two pulses per cycle are derived from the 25-cycle waves, the largest scale is 0-20 milliseconds. In addition to this scale, there are seven scales, each of which has a range of 5 milliseconds.

These latter scales are located in successive positions throughout the 20-millisecond range, with 2.5-millisecond overlap between adjacent scales, and are obtained by a d-c bias which simply shifts the scale but does not change its delay range. When either extreme of the 0-20-millisecond range is reached the meter shifts abruptly to the opposite extreme so that operation at these points is not feasible. A means is provided in the instrument for shifting to a more favorable position in the 0-20 range.

The voltage on one plate of the flip-flop is amplified by a long time constant R-C stage to provide a 0-1 millisecond scale. Inverse feedback in the cathode further lengthens the time constant. A meter between the cathodes of this stage provides an indication of relative delay. Also, the voltage on one of the cathodes provides the oscilloscope display of relative delay. Since the oscilloscope gain is adjustable over a wide range, it may be used to indicate a greater range of delay characteristics than the meter.

Perhaps an explanation of why 50 pulses rather than 25 pulses per second was selected is of interest. In the original experimental model using one pulse per cycle of the 25-cycle waves, considerable difficulty was encountered due to false delay variations arising from rapid changes in received signal level. The corresponding changing d-c levels from the demodulator shifted the signals up and down in the clippers with respect to the clipping axis, resulting in small variations in the clipping points on the 25-cycle waves. Here a shift as small as 0.1 degree in the clipping points on the 25-cycle waves is undesirable. The resulting false delay variations were many times larger than could be tolerated. This situation was corrected by using a method involving two pulses per cycle instead of one pulse per cycle. In this case, each of the two pulses is shifted in opposite directions as the signals shift with respect to the clipping axis, so that each cancels the effect of the other and the correct reading for actual delay results. In addition, another advantage is realized in that the maximum delay scale is 0-20 instead of 0-40 milliseconds because the flip-flop output current reaches its maximum value every 180 instead of every 360 degrees of shift in the 25-cycle waves. The sensitivity is thus doubled.



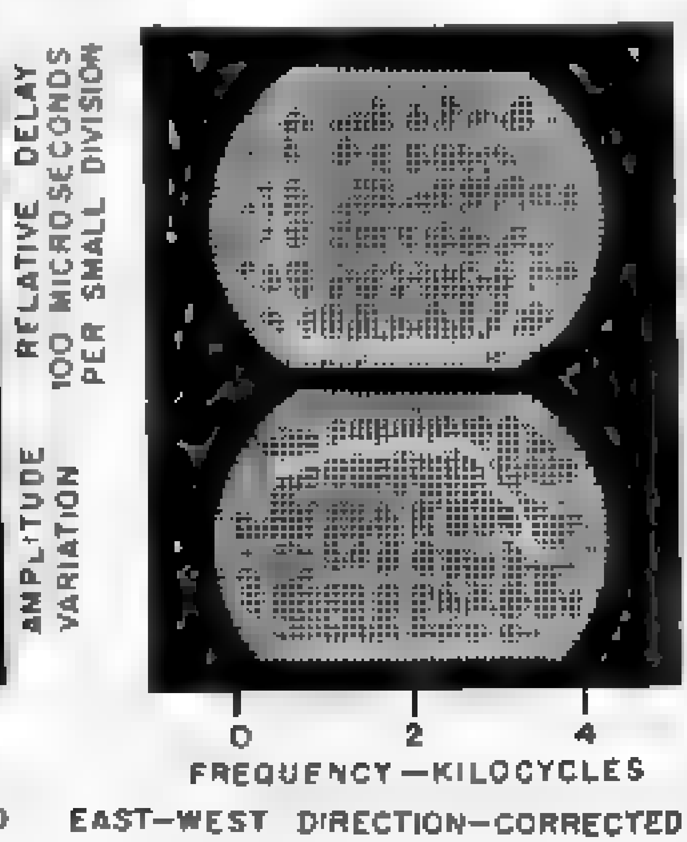


Figure 7. Relative delay and amplitude oscillograms—5-section Type K

Performance

The instrument was developed primarily for use in conjunction with corrective networks for equalizing of delay and amplitude characteristics of facsimile circuits. For this purpose, it is necessary to use a separate instrument at each end of the circuit permitting the corrective procedure to be followed in either direction. Once the instrument has been set up, the corrective procedure may begin. The frequency of the sweep oscillator at the transmitting end is swept across the desired range. The corrective devices are located at the receiving end. The level meter and delay meters, or oscilloscope if used particularly to make permanent records, indicate amplitude distortion and delay distortion.

In the use of passive corrective networks, it is usual to make correction for amplitude distortion first since passive delay corrective networks can be made practically free of amplitude distortion but purely amplitude corrective networks possess delay distortion. However, active corrective networks are now available in which both delay and amplitude correction can be made independently of each other by adjustment of resistors only. In the use of the instrument as each new corrective insertion is made, the remaining correction necessary for equalization and the position in the spectrum where the correction is needed may be determined quickly from the delay, level and frequency meters. The process of observation and correction is continued until the delay and amplitude variations are within prescribed limits.

The instrument is presently designed to cover a frequency range of approximately 200 to 12,000 cycles. The sweep oscillator can be set to sweep this entire range or any portion of this band not less than about 900 cycles in width. Over this range the delay and amplitude characteristics due to the instrument circuitry are essentially constant. The transmitter output level to the line is adjustable in five steps from +10 dbm to −10 dbm. The receiver will operate stably for constant input levels from the line over a range from approximately −35 dbm to +20 dbm with appropriate pad settings. With a varying input level from the line and a fixed pad setting, the receiver will operate over a variation of at least 30 db within this [illegible]

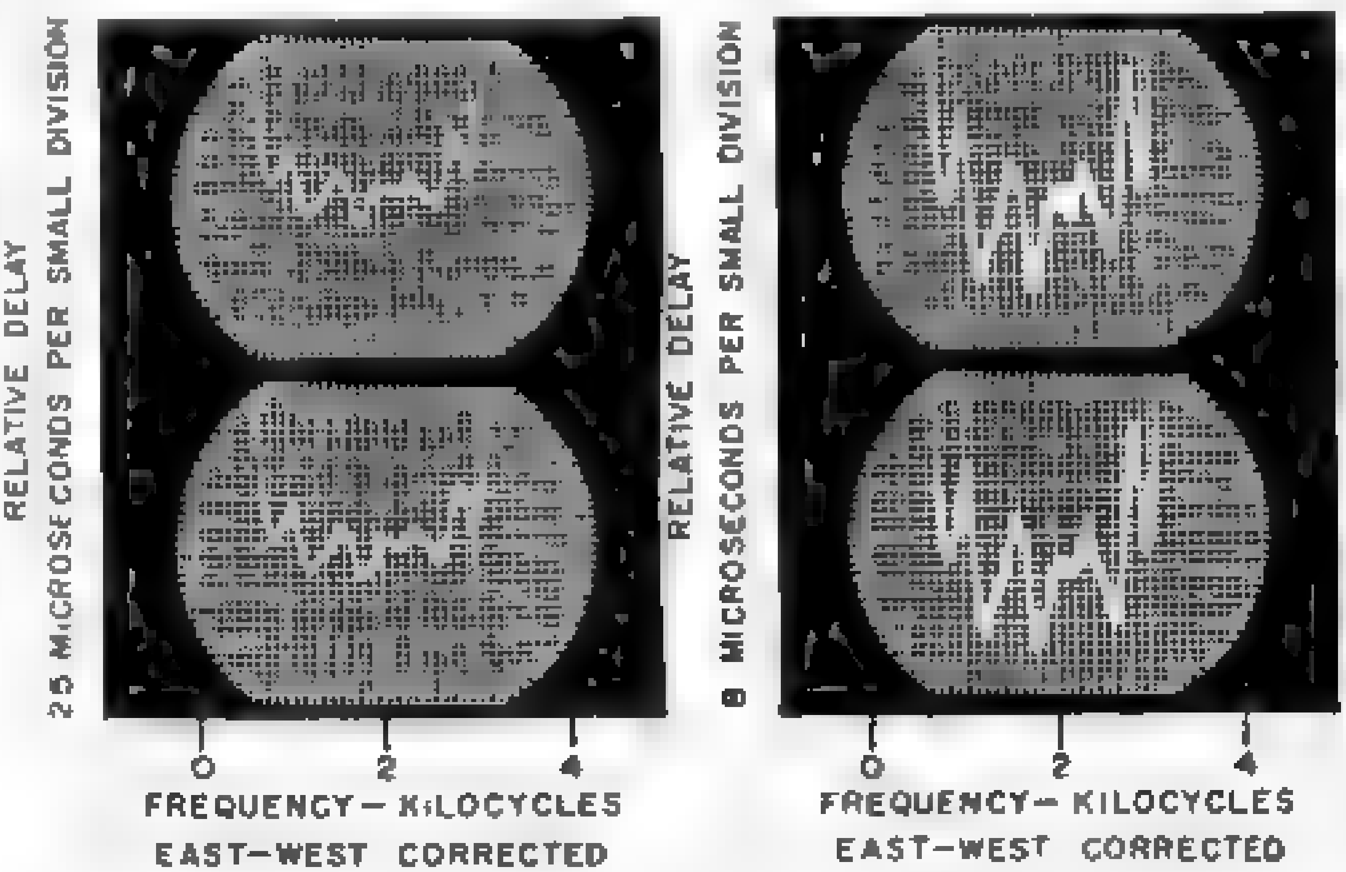


Figure 8. Relative delay oscillograms—5-section Type K

The accuracy of the instrument depends largely upon the means used to display the information, the type of measurements desired, and the characteristics of the circuits or equipment required to be measured. Under favorable conditions particularly those in which the delay characteristics are relatively flat throughout the frequency band under consideration, an accuracy of approximately ±10 microseconds may be attained. For conditions in which large delay variations are encountered the accuracy attained is considerably less, extending to approximately ±50 microseconds. For external displays, such as an oscilloscope display the accuracy depends upon the precision with which the frequency, delay and amplitude axis settings are made. In any case, the delay information can be checked by the insertion of known delay values for which one means is provided in the instrument. Typical oscilloscope displays are shown in Figures 7 and 8.

These oscillograms were made using a long five-section Type K circuit both uncorrected and corrected in which only a partial correction was made for amplitude distortion. The delay distortion correction is effective in producing a flat characteristic throughout the useful frequency band to within approximately ±100 microseconds. Two records were made on each oscillogram of Figure 8 at expanded scales of approximately 25 and 8 microseconds per small division in order to determine the effect of circuit noise occurring in long circuits on the performance of the instrument. It will be observed that the resulting disturbance is small and that the departure in relative delay between the two traces of these oscillograms within the useful frequency band does not exceed approximately ±10 microseconds.

Aside from its use in the correction of delay and amplitude distortions in which the instrument greatly exceeds the accuracy requirements, it is finding use in other applications where greater accuracy is required. In these applications, the instrument may be used to measure and make permanent records of the characteristics by the sweep method or by point-by-point methods particularly where greater accuracy is required for absolute measurements on a loop basis.

The development of the instrument described in this paper was one phase of a comprehensive investigation of facsimile signal transmission conducted by the Western Union development and research organization under U. S. Army Signal Corps sponsorship.

Acknowledgments

The author gratefully acknowledges the guidance and assistance of many people concerned with the measurement of envelope delay and measurement and correction of delay distortion. Special thanks are given to Henry F. Burkhard and Chester S. Friedman of the U. S. Army Signal Corps, F. B. Bramhall, Transmission Research Engineer, D. J. Bertuccio, Harold Gück, E. S. Grimes and T. Rystedt of The Western Union Telegraph Company.

References

1. The Building Up of Sinusoidal Currents in Long Periodically Loaded Lines, JOHN R. CARSON, *Bell System Technical Journal*, October 1924.
2. Phase Distortion and Phase Distortion Correction, S. P. MEAD, *Bell System Technical Journal*, May [illegible].
3. Measurement of Phase Distortion, H. NYQUIST and S. BRAND, *Bell System Technical Journal*, May [illegible].
4. Phase and Amplitude Distortion in Linear Networks, M. J. DiTORO, *Proceedings of the IRE*, January 1948.

Mr. Cannon's biography appeared in the April 1955 issue of Technical Review

HENRY M. STOMMEL, Physical Oceanographer, Woods Hole Oceanographic Institution

Electrical Data From Cable May Aid Hurricane Prediction

In January 1952, Henry M. Stommel, one of the Physical Oceanographers on the research staff of the Oceanographic Institution at Woods Hole, Mass., mentioned to General Plant Engineer C. S. Lawton, of the Western Union International Communications Department, that as a result of some theoretical work on electric fields produced in ocean water due to its motion through the earth's magnetic field, there was reason to believe the total transport of water at any time in the Gulf Stream could be determined from the difference of voltage in the water at the two sides of it.

Of the several cables crossing the Gulf Stream, those across the Florida Straits seemed most suitable for obtaining the desired measurements, which could be made during periods when a cable normally would be free of traffic. Suitable electrodes had been designed and the Western Union traffic people were glad to cooperate by releasing No. 2 KZ HVA cable for this purpose over consecutive week ends. After a short lapse this summer, measurements begun by Western Union in June 1952 have been resumed and will continue as long as desired by the Institution.

In 1952 the possibility of a relationship existing between the variations in water transport and the breeding of hurricanes was not in the picture, but in the following article Mr. Stommel gives a striking example of how the pursuit of pure science can lead to a discovery which may prove to be of practical significance in everyday life.

Since August 1952 measurements of the electric potential between two silver-chloride electrodes—one situated at Key West, Florida, off the Western Union cable hut in about four feet of water and the other in eight feet of water inside the harbor entrance at Cojimar, Cuba, 3.8 nautical miles east of Havana—have been made on Western Union cable No. 2. The idea behind these measurements has been that the sea-water, an electrical conductor moving through the earth's magnetic field, must generate an electromotive force of about one volt across the Florida Straits, and that this voltage varies as a function of the discharge or velocity of the ocean current flowing through the Straits.

It is of considerable oceanographic interest to obtain records of the variability of ocean currents because very little definite knowledge exists. The Florida Current is of particular interest because it is a direct continuation of the surface current flowing through the Caribbean Sea from the region of the northeast Trades bounded by the 10-degree and 20-degree North latitude circles, and the meridians of the Cape Verdes on the east,

KEY WEST–HAVANA CABLE

Electrical measurements on Western Union cable indicate ocean current through Florida Straits varies from 14 million to 39 million cubic meters per second.

the Windward Islands on the west. This vast expanse of the tropical Atlantic is the breeding ground of hurricanes.

It seems possible that the year-to-year variability in the numbers of hurricanes generated in this area must depend upon the evolution, during any particular summer season, of the thermal structure of the surface layers of the sea. In years when the Trades are weakest the surface layers will lose less of the heat they absorb from the sun by vertical mixing with cold lower layers. Also the surface currents, being weaker, will carry less heat away from the area. These years thus will be years of highest summer and fall surface temperature. They will provide in abundance the heat energy which young hurricanes need in order to grow

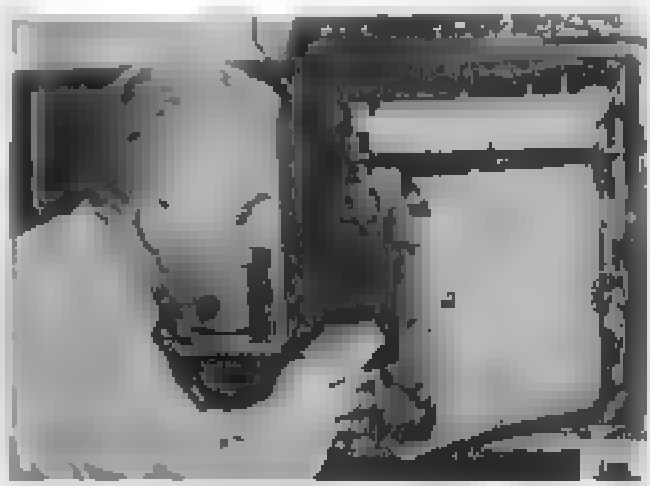
There is, however, very little regular meteorological data reported from this unfrequented area of the ocean and so it is not easy to test this conjectured sequence of cause and effect. Since the Florida Current is fed by this very area, it is important to determine whether its discharge can serve as an index of the strength of the Trades integrated over the tropical Atlantic. Should this really prove to be the case, the potential measurements across the Florida Straits might prove of considerable practical importance; they *might provide several months' advance warning of a particularly bad hurricane breeding season.* At present the duration of the series is not long enough to present a clear-cut case one way or the other

At the time the measurements were begun, their possible applicability to the hurricane problem was not envisaged The only reason for making them was to record an important oceanographic variable, and curiosity to see whether an ocean current could really induce a measurable electrical potential

Method of Measurement

The potential measurements made at Key West, under the supervision of Western Union cable technician P J Moore, use a recording potentiometer (a Leeds-Northrup Speedomax) with 10 millivolts full scale, and a chart speed of one inch per hour. The actual voltage between the electrodes being roughly one volt, it is necessary to introduce a series resistor between the electrode connections and the recorder

The relation between the cross-stream potential difference, the induced e.m.f., and the flow of the ocean current is complicated, because the ocean water and the rocks beneath it offer a wide variety of paths through which the electric current can flow. In most circuits employed in engineering practice the flow of electrical currents is restricted to networks of insulated wires. In nature electrical currents flow through a continuum of variable resistivity The e.m.f. induced in those portions of the continuum which are moving (the ocean current) is readily computed, however, it is proportional to the vector cross-product of the fluid velocity and the magnetic field vector, and at right angles to both of them



Western Union cable technician P J. Moore of Key West Florida checks an automatic voltage recorder connected with one of Western Union's Key West-Havana cables The 24-hour chart indicates that about 10,000,000,000 gallons of water flow every second in the Gulf Stream between Key West and Havana.

In the Florida Straits between Key West and Havana, where the water flows toward the east, and the magnetic vector points downward toward the north, the e.m.f. vector lies in a vertical plane oriented in the north-south direction (cross-stream) and points toward a point somewhat above the Northern horizon. The magnitude of the e.m.f. vector is strongest near the surface of the Florida Current where the water velocity is greatest, and

weakest at depth where the water velocities are low

The field of electrical potential which develops as a result of the field of induced e.m.f. depends upon the distribution of conductivity in the water and ocean bottom below, and the resulting field of electrical currents. To obtain a quantitative answer concerning the relation of the potential and current density to the field of induced e.m.f., one must solve a mathematical problem in partial differential equations.[1] A qualitative picture of what is involved can be conveyed as follows. For example, if the bottom rocks were highly conducting they would effectively short out the e.m.f. induced in the moving water above, and the measurable difference across the current would be very weak. Actually the bottom has a conductivity roughly one-thousandth that of sea-water so that it acts only as a very weak shunt across the bottom of the channel. So far as can be determined, the voltage across the Florida Straits is reduced less than 10 percent by bottom shunting effects.

The layers of slowly moving bottom water do act as shunts on the e.m.f.'s of the more rapidly moving surface layers in much the same way as weak electrochemical cells in parallel with strong ones provide return circuits for the latter and hence reduce the over-all voltage developed. It can be shown that this interplay between the different layers results in a horizontal cross-stream potential gradient very nearly equal to that which would be generated by a vertically uniform water velocity equal to the vertical average of the actual velocity distribution.

This fortunate fact, coupled with the high resistivity of the bottom rocks, makes the relation between the total discharge of water through the Florida Straits and the difference of voltage at either side quite simple. In a channel of uniform depth

$$T = \frac{Vd}{H_z}$$

where T = water transport in cubic meters per second,

V = electrical potential difference in volts,

d = depth of water in meters,

H_z = vertical component of the geomagnetic field in webers per square meter.

In the Florida Straits the depth is not uniform. The same total discharge would produce a different voltage difference if it were found to flow over a shallow portion of the channel than what it would produce when flowing over a deeper portion. It is not known to what extent the variability of cross-stream potential difference observed across the Florida Straits is due to lateral shifting of the axis of the current from deep to shallow water.

Observed Variability of the Current

The results of the first year's observations have been published by Gunther Wertheim.[2] He has also analyzed the second year's observations in an unpublished manuscript. The third year's data are being analyzed by Robert Ward. The records exhibit a very wide range of variability. In the following it is assumed that none of this is due to lateral shifting of the Stream.

Short-Period Variability

The geomagnetic disturbance of short-term nature, which cable engineers refer to as "earth currents," is much smaller on this route than most, the present data showing it to be limited to something under 10 millivolts per kilometer length of cable. However, it should be remembered that the route between Havana and Key West is more closely parallel to the direction of the lines of force in the earth's magnetic field than that of most cables. It is along the long east-west routes that the much larger disturbances commonly referred to by cable engineers are experienced for short intervals during occasionally violent "magnetic storms."

Tidal Periods

The amplitudes and phases of the tides at the Atlantic Ocean and Gulf of Mexico ends of the Florida Straits are different.

Hence there are tidal currents. Fortunately the hydrodynamical theory of tidal currents in long channels is sufficiently developed to permit calculation of the discharges of the tidal currents through the Florida Straits from the tide levels observed at tide gauges installed along the banks of the Straits. In this way it is possible to make a check on the transports inferred from the electrical measurements by comparing them with the transports deduced from the independent tide gauge data. As Wertheim has shown, the comparison is a good one. This gives increased confidence in the interpretation of the electrical measurements for the longer-period variations for which there is no suitable independent means of comparison. The transports associated with the tides are about 15 percent of the average Florida Current.

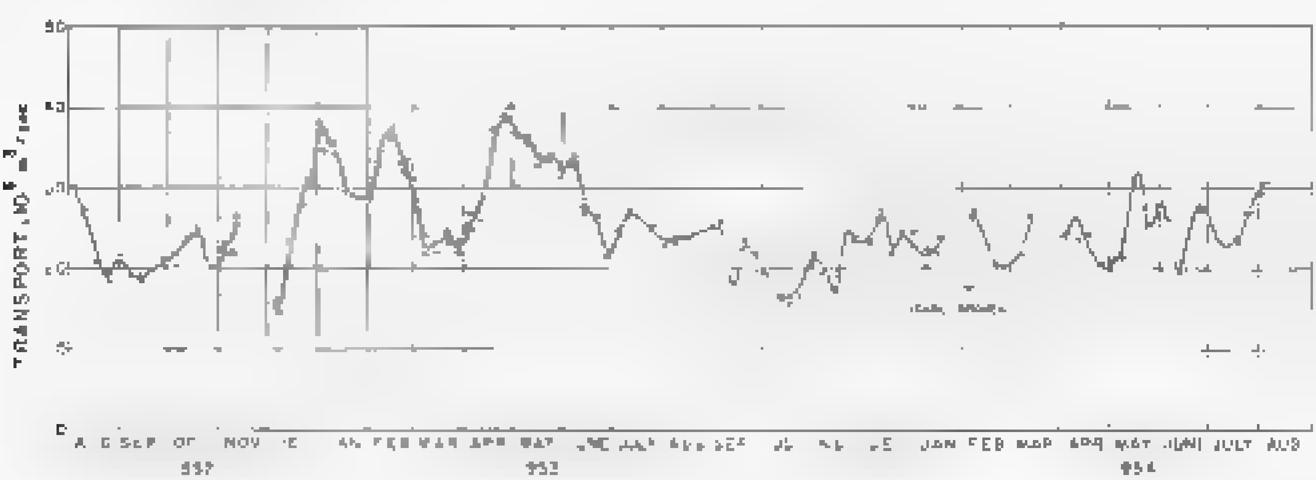
Daily Averages

Enough data are obtained each weekend so that two daily averages may be computed. A 24-hour average essentially filters out the semidiurnal and diurnal tidal signals. These transport values for the first two years of operation are exhibited in the illustration. From an oceanographic point of view the most interesting feature of this curve is the periods of anomalously large transports centered at January 1, February 15 and April 25, 1953. In the winter of 1953-4 there were no such anomalous surges of the current—thus indicating very considerable year-to-year differences in the variability of flow.

Attempts to relate this variability to North Atlantic weather maps have not been very satisfactory. Perhaps the most promising lead has been the fact that each of the periods of maximum flow of the Florida Current was preceded by about a month by a period of marked weakening of the northern fringes of the Trades. At first sight it might seem that such a relation is precisely contrary to the common-sense view: *strong winds mean strong currents*. The justification for this picture is that a weakening of the northern fringes of the Trades allows a certain fraction of the Equatorial Current, which would normally flow north of the West Indies, to flow through the Caribbean and hence increase the Florida Current after about a one-month time lag.

Before these data were available there were no systematic measurements of the flow of a large-scale ocean current and hence no quantitative picture of how variable these currents actually are. The variability of the Florida Current observed during the past three years has exceeded expectation. The lowest 24-hour average discharge was 14,000,000 cubic meters per second, the highest 39,000,000. For comparison, the average discharge of the Mississippi River is roughly 10,000 cubic meters per second.

The average flow for the first year (August 1952—July 1953) was 27 million cubic meters per second, for the second year (August 1953—July 1954) was 23 million. This is really a very large variation in the yearly average. On such a lim-



Mass transport of the Florida current

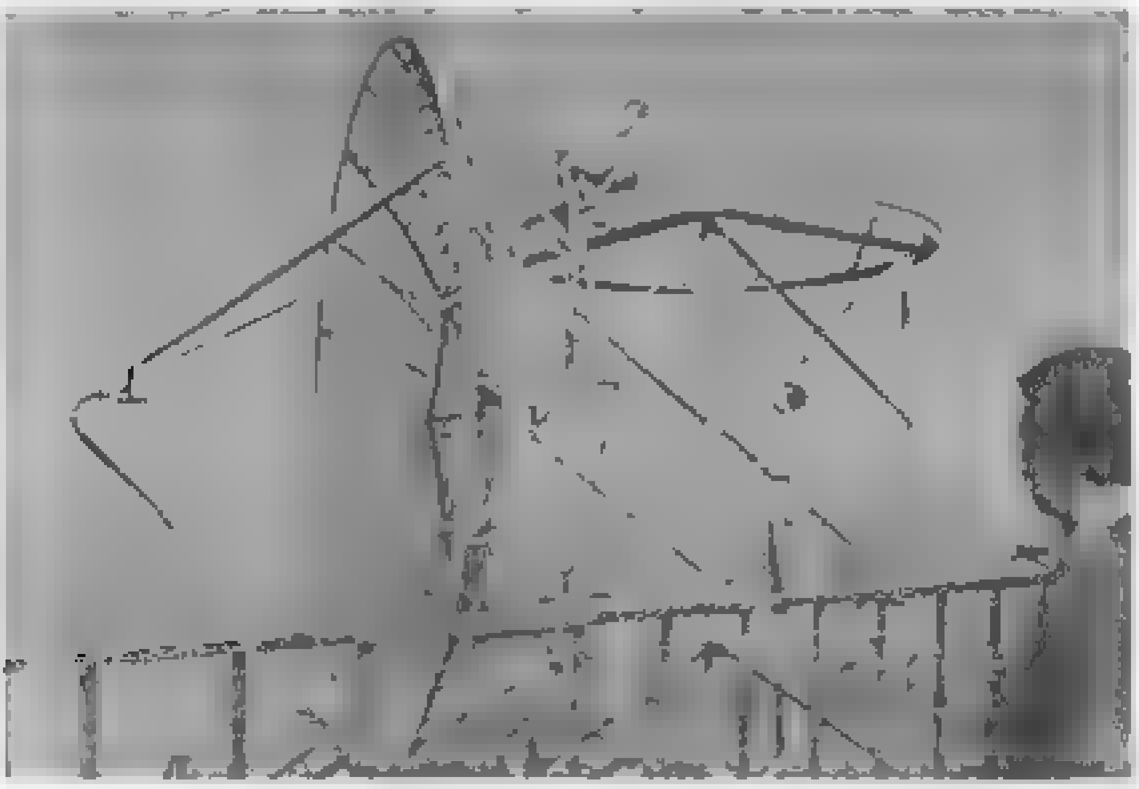
ited series of data one can scarcely hazard a guess that the second year's lower discharge reflects generally weaker Trades (in distinction to the northern fringes), and that this might be related to the severe hurricane season of 1954. But the possibility of such a relation is there. That is one of the reasons the Florida Current measurements are so interesting and are well worth continuing.

References

1. M. S. Longuet-Higgins, M. E. Stern, Henry [illegible] Papers in Physical Oceanography and Meteorology, Woods Hole Oceanographic Institution and Massachusetts Institute of [illegible]

[illegible] K. [illegible] Studies of the Electric Potential [illegible] Key West, Fla. and Havana, Cuba [illegible] American Geophysical Union, Vol. 35 [illegible] December

Experimental Microwave Antenna



An 18-foot paraboloidal reflector antenna for microwave research has been erected above the Western Union main radio laboratories at the company's headquarters in New York. The antenna is mounted on a 25-foot steel tower and track to permit rotation through 360 degrees in azimuth to cover the entire horizon, giving maximum flexibility for experimental purposes.

Initially, the new antenna is being employed for beyond line-of-sight tropospheric radio signal propagation tests between New York and Philadelphia, a distance of about 84 miles. The reflector was made by D. S. Kennedy & Co., at Cohasset, Mass.

Considerable effort is being directed by both military and civilian organizations toward the use of so-called tropospheric scatter or beyond-the-horizon transmission. A large amount of information is being obtained on propagation of this type and with the availability of new high power transmitting tubes covering the higher frequency ranges it is expected that there will be many additional applications of such systems.

It is not expected that beyond-the-horizon circuits will replace line-of-sight systems, but rather will be used where terrain or other factors are controlling. Line-of-sight systems continue to increase as evidenced by Western Union's plans for extending its existing circuits from Pittsburgh to Cincinnati and Chicago in 1956, and the modification of its present system between New York, Washington and Pittsburgh to double the traffic handling capacity.

HOWARD C. ISAACS, Engineer, Systems and Equipment

Transistor Type Transmitter-Distributor

PRINTING telegraph systems employ transmitter-distributors to read perforated paper tape and to transmit signals to line in serial fashion. In addition to signal elements derived from holes punched in the tape, each transmitted character contains a start element at the beginning and a stop element at the end.

Conventional transmitter-distributors are almost wholly mechanical in design with tape sensing accomplished by

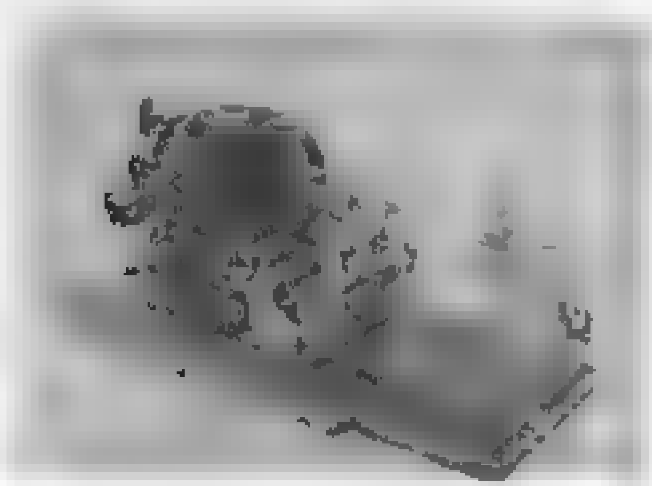


Figure 1 Conventional type transmitter-distributor

mechanically operated sensing pins coupled to contacts. The distributor is motor driven and either operates an assembly

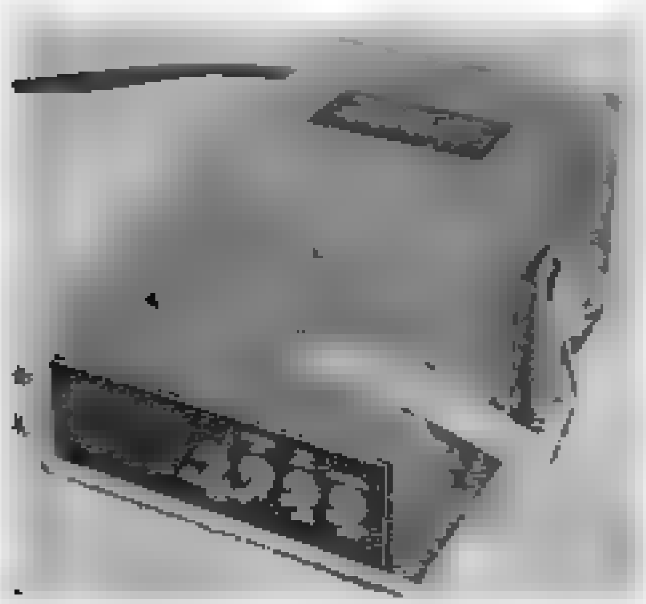


Figure 2 Model transistor type transmitter-distributor

of cams to actuate contacts (see Figure 1) or rotates brushes to scan a segmented faceplate.

The degree of maintenance required to service the mechanically moving parts of a conventional transmitter-distributor is tolerable in commercial operation at ordinary printing telegraph speeds. For Signal Corps requirements, however equipment research engineers of the Telegraph Company have developed the transistorized transmitter-distributor described here in which mechanical components have been replaced with transistor circuitry

Design Requirements

The design requirements for the Transistor Type Transmitter-Distributor developed under the Signal Corps contract are unusual. Not only does the final model sense standard fully perforated tape and perform the usual function of a transmitter-distributor, but it also has the following features.

1. Tape sensing is accomplished by means of a light source and photodiodes

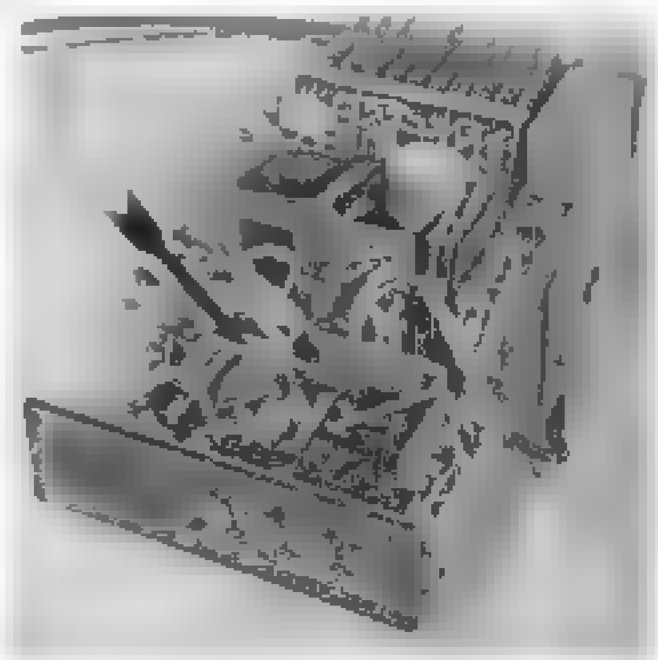


Figure 3 Transmitter-distributor with cover removed Arrow indicates tape-reading unit including photodiodes

2. Conversion of the photodiode output into start-stop telegraph signals is accomplished by means of transistor circuits.
3. The output speed is 100 or 250 words per minute.
4. Signal distortion is less than 5 percent.
5. Means for single-character-stepping is provided.

The experimental model is reliable in operation and mechanically simple, all functions being performed electronically by means of transistor circuitry with the exception of tape-stepping, which is mechanical.

1.1 percent, but this loss was considered to be a small sacrifice compared with the advantages gained through simplified circuitry for, with a 7.5-unit code, a free-running oscillator could be employed. The Signal Corps accepted this recommendation. The model Transistor Type Transmitter-Distributor is pictured in Figures 2 and 3, with and without cover.

Over-all Block Diagram

Figure 4 is a block diagram of the transmitter-distributor. An 8-stage ring counter is shown at the top of the diagram, the

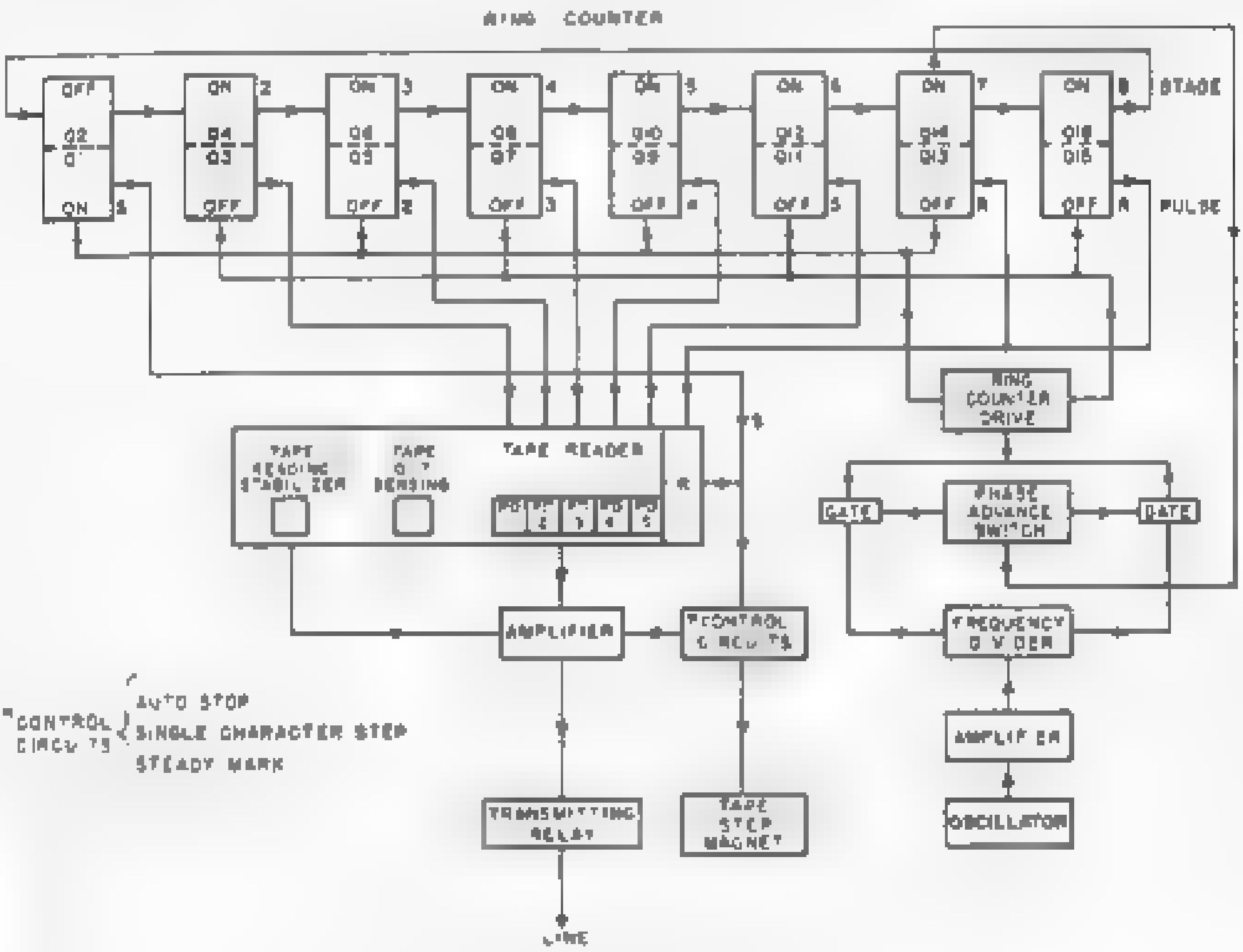


Figure 4. Block diagram of transmitter-distributor

The Signal Corps originally specified that signal distribution be in accordance with the standard 7.42-unit Baudot Code, but it was proposed that a 7.5-unit code be utilized in order to simplify the design by eliminating the need for a start-stop oscillator and a timing circuit. Use of a 7.5-unit code instead of a 7.42-unit code would reduce the speed in characters per minute by

photoelectric tape reader and the signal transmission to line are indicated in the center, and below the tape reader are the control circuits and the tape-step magnet. Starting at the bottom right and proceeding upward are shown the oscillator and associated circuits for stepping the ring counter.

The oscillator is connected to an am-

plifier which operates a bistable transistor trigger circuit, which in turn acts as a frequency halver This frequency divider has two outputs, each of which delivers pulses at one-half of the oscillator frequency and 180 degrees out of phase with the other These outputs are connected to two separate gates controlled in such a manner that when one gate is open the other is closed, the condition of the gates is controlled by the phase-advance switch.

The output of the gates is connected to the ring counter drive circuit which is also a bistable transistor trigger circuit from which two outputs are derived. One output is connected to the odd-numbered stages of the ring counter and the other to the even-numbered stages. It may be noted that splitting the drive circuit into two paths in this manner is feasible when the ring counter comprises an even number of stages. Also, this has an important advantage in stabilizing counter operation because at the time a stage is being turned ON there is no opposing pulse tending to turn it OFF

Each stage of the ring counter consists of a two-transistor bistable trigger circuit Of course, only one stage at a time may be ON A stage is considered to be active or ON when its odd-numbered transistor, Q-1 to Q-15 is ON When a stage is active its even-numbered transistor is OFF, and all the even-numbered transistors of the other stages are ON In the block diagram, the first stage of the counter which is used to time the transmission of the start pulse is shown active; that is, Q-1 is ON and Q 2 is OFF The remaining odd-numbered transistors Q-3 to Q-15 are OFF and the remaining even-numbered transistors Q-4 to Q-16 are ON

This condition persists until a drive pulse is applied from the left-hand output of the ring counter drive circuit to the odd-numbered counter stages. Q-1 is turned OFF by this drive pulse thus rendering stage 1 inactive. At the same time Q-2 is turned ON and, in so doing, a pulse is generated which turns Q-4 OFF and consequently turns Q-3 ON In this manner stage 2 becomes active.

It should be noted that when Q-3 was turned ON, unlike with some counting circuits, there was no output from the drive circuit simultaneously tending to turn Q-3 OFF. Therefore, the circuit will tolerate considerable variation in amplitude and shape of the drive pulses. This is the purpose in directing the drive pulses alternately to the odd- and even-numbered stages and, as was mentioned previously, it may be done only when an even number of counter stages are employed. However, splitting the drive pulses into two paths in this manner is not essential to the development of the 7.5-unit code

At this point stage 2 is active; that is, Q-3 is ON and all the other odd-numbered transistors are OFF; Q-4 is OFF and all other even-numbered transistors are ON Assuming that the left-hand gate is open and the right-hand gate closed, every second cycle from the oscillator generates a pulse which finds a path through the left-hand gate and the drive circuit to the counter. The next such pulse passing through to the ring counter drive generates a stepping pulse which turns stage 2 OFF and stage 3 ON The following pulses successively turn stages 3, 4, 5, 6 and 7 OFF Upon turning stage 7 OFF and stage 8 ON a pulse is generated which triggers the phase-advance switch.

The condition of the two gates is reversed when the phase-advance switch is operated and thus the left-hand gate is closed and the right-hand opened. Now instead of waiting for the second cycle of the oscillator to produce the ring counter stepping pulse the very next cycle following the one which turned stage 7 OFF will be gated through the right gate and will turn stage 8 OFF, thereby limiting the active period of stage 8 to one-half that of the other stages. On the next counter sequence the drive pulses are derived through the right-hand gate until after the 7th stage has been turned OFF, when the phase-advance switch is again operated and the condition of the gates is again reversed

The ring counter and photodiodes PD-1 to PD-5 are connected, as shown in the block diagram, to effect the proper signal distribution. Stage 1 provides a spacing or start interval The next five stages are connected to photodiodes PD-1 to PD-5 to

effect the distribution of the intelligence pulses. The 7th and 8th stages are combined to provide a marking interval of 1.5 units for the rest pulse. When a photodiode is illuminated a marking code pulse is transmitted at the time the particular ring counter stage associated with that photodiode has its odd-numbered transistor conducting. A marking rest pulse is always transmitted when the odd-numbered transistors of stages 7 and 8 are conducting, thus completing the start-stop signal.

The marking code pulses and the rest pulses are amplified and the amplified signal operates a transmitting relay. The rest pulse is also directed to the control circuits to time the auto-stop, tape feed and single-character-stepping functions.

Control Circuits

The functions of the control circuit, a block diagram of which is shown in Figure 5, are (1) Tape stepping, (2) Starting and stopping of transmission and (3) Single character stepping.

Tape stepping is accomplished as follows. The rest and start pulses are amplified and applied to the tape-step gate which is controlled by the auto-stop flip-flop. With the tape arm in its normal position, the state of the auto-stop flip-flop is such that the tape-step gate is open. The rest and start pulses are amplified and applied to a power transistor which supplies sufficient current to drive the tape-step magnet.

To stop transmission, the tape arm is moved upward, directing the output of the control amplifier to the other half of the auto-stop flip-flop. A sharp negative pulse at the beginning of each rest pulse is derived from a differentiating network following the control amplifier. This negative pulse reverses the condition of the auto-stop flip-flop and closes the tape-step gate, thus further tape stepping is stopped. At the same time the tape-step gate is closed a steady mark circuit is activated which supplies a steady marking signal to the line.

While in the auto-stop or idle condition, it is possible, by manually operating a push button, to step the tape one character at a time and also to transmit that character to the line. Closure of the single-step button causes a pulse to be transmitted from the single-step gate to the auto-stop flip-flop at the beginning of the rest interval, the auto-stop flip-flop, as a result, assumes its transmit position. Steady mark is removed from the line (still held marking by the generated rest pulse) when the tape-step gate is opened, and the tape is stepped to the next character which is sensed and transmitted. The circuits are so arranged that the following rest pulse will turn the flip-flop back to the stop position even though the single step button remains closed. Turning the flip-flop back closes the tape-step gate and again places a marking signal on the line. There-

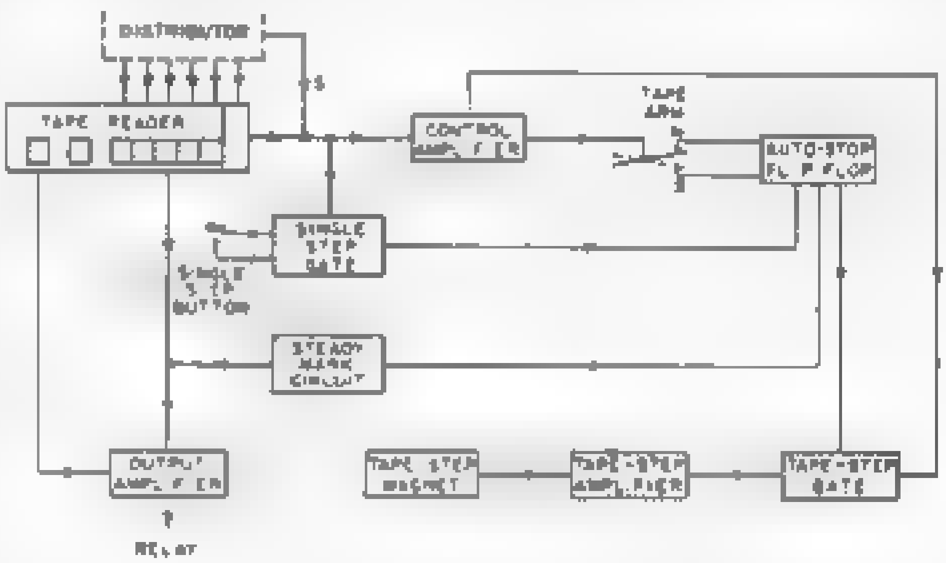


Figure 5. Block diagram of control circuit

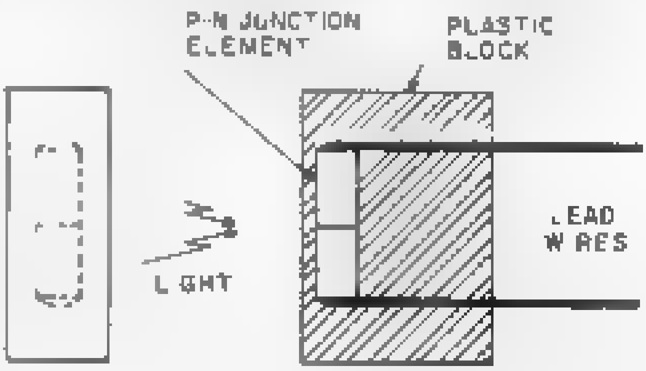


Figure 6. Front view and side section of photodiode

after another single-step operation can be obtained only if the single-step button has been opened and then closed again.

To start transmission, the tape arm is allowed to regain its normal low position. The next rest pulse causes the auto-stop flip-flop to assume the transmit position and as a result steady mark is removed and the tape-step gate is opened. The tape is then stepped and the next character is sensed.

The tape-reading unit is composed of seven Type 1N85 photodiodes (see Figure 6), each measuring 1/4 by 3/16 by 3/32 inch. Incident light strikes the light sensitive germanium area through one of the 1/4 by 3/32 inch faces. Leads are taken out of the opposite face. The lateral surfaces are painted black. The dimensions of the photodiodes are such that five may be placed side by side, with an appropriate spacer between the second and third, so that the active surface of each photodiode coincides with the perforations of standard tape. Tape is fed over the tape reader and is illuminated by a straight line filament light source. Adjacent to the fifth pulse photodiode is another which normally is under the solid portion of the tape but when exposed to light, under the condition of tape-out, causes a steady marking signal to be applied to line.

A seventh photodiode, the tape-reading stabilizing photodiode, is placed adjacent to the first intelligence pulse photodiode and is continually exposed to light. It is connected in a bridge-type circuit and balances out any variations in signal output due to variations in tape translucency, lamp voltage and 120-cycle modulation produced by the a-c energized light source. The stabilizing circuit also applies steady marking signal to the line in case of lamp failure or accidental release of the tape latch.

Circuit Considerations

Some circuit considerations follow. With the exception of the oscillator, amplifiers, and some gating circuits, the other blocks of the system are composed of bistable trigger circuits such as seen in Figure 7. This circuit operates over a wide range of supply voltages and input pulse amplitude.

The oscillator, Figure 8, is of the Hartley type. The diode connected across the tank limits the a-c voltage there and keeps the a-c tank voltage constant with temperature variations. A resistor is placed from emitter to collector of the oscillator transistor to provide a feedback path, limiting frequency changes that would result from variations in supply voltage.

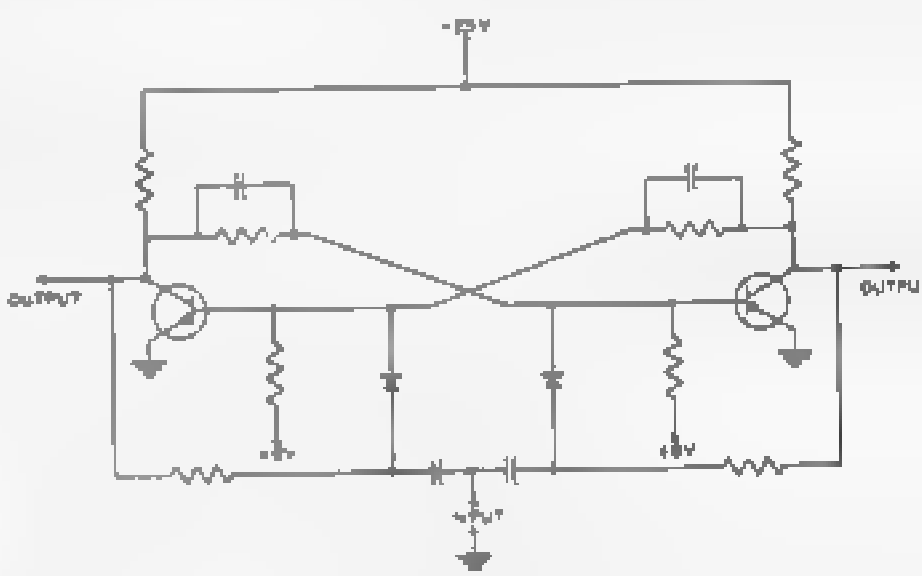


Figure 7 Bistable trigger circuits

The oscillator output is shown in Figure 9.

Heat tests were conducted with the oscillator with very favorable results. The oscillator frequency increased 1 percent when the temperature was raised from 25 to 50 degrees C. A further increase in temperature to 55 degrees C increased the oscillator frequency 2 percent. The supply voltage may be varied through the range of 105 to 130 volts with a negligible (less than 1 percent) change in the oscillator frequency.

A double-pole, double-throw switch is included in the oscillator circuit to enable the operator to select the transmission rate of either 100 or 250 wpm. The switch selects the tank coupling capacitor required for each speed. A potentiometer placed in

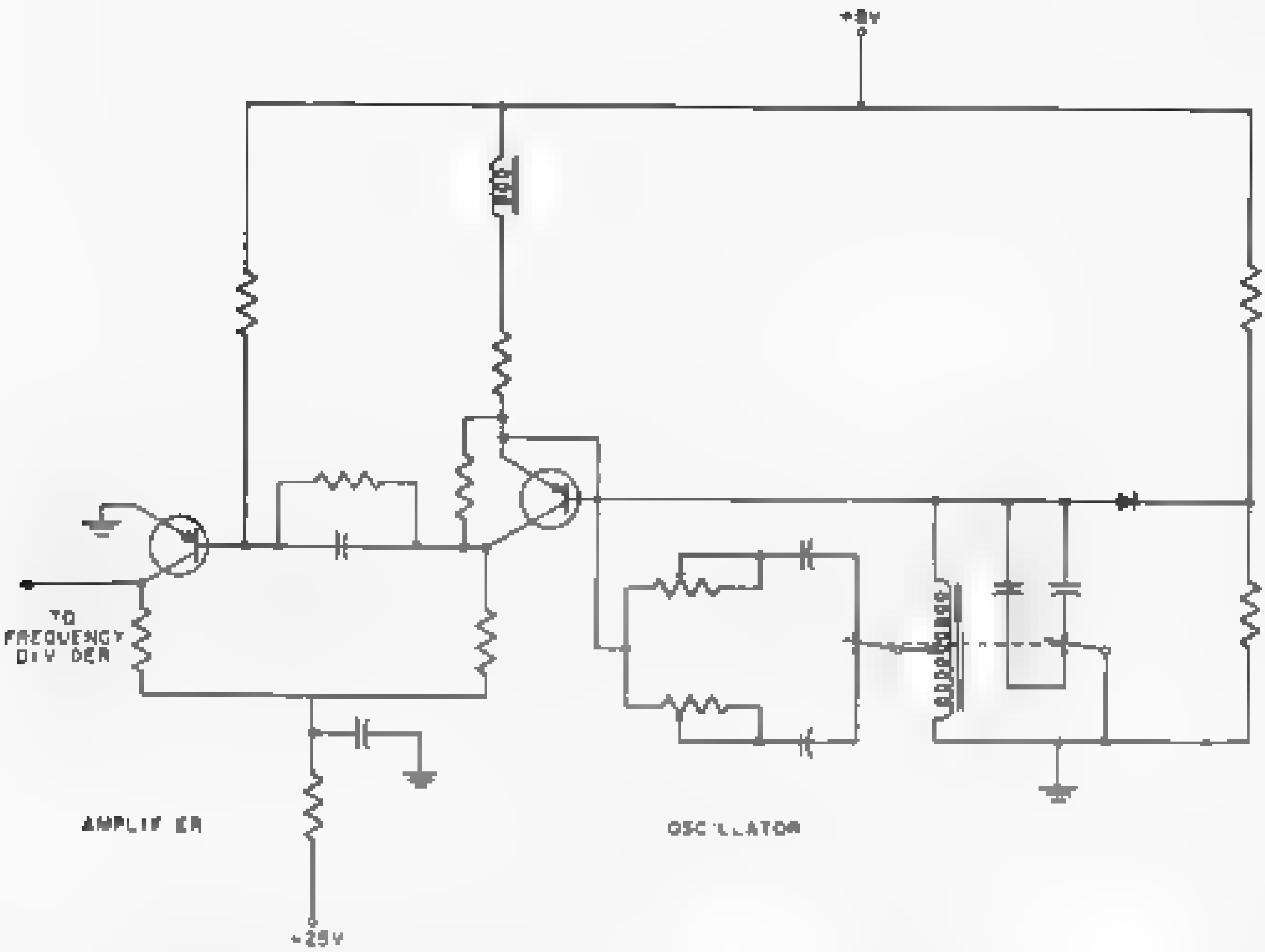


Figure 8. Oscillator

series with each coupling capacitor allows each discrete speed to be varied slightly for test purposes where speed synchronization is necessary. In order to provide the necessary pulse amplitude to operate the frequency divider, a stage of amplification is required.

Starting of the ring counter is accomplished automatically upon the application of power to the unit but before the counter may be pulsed, certain initial conditions must be met (see Figure 4). Only one odd-numbered transistor, Q-1 for example, may be in the ON condition to satisfy the initial conditions necessary for starting. To establish this condition, a delay circuit is inserted between the power supply and the ring counter so as to delay the application of voltage to the collectors of all even-numbered transistors except Q-2. The collector voltage of transistor Q-1 is also delayed, and all transistors so affected are biased negatively or conditioned ON while the remaining transistors are biased positively or conditioned OFF. After the delay interval is passed and full voltage is applied to the collectors, the counter assumes the proper start condi- [redacted]

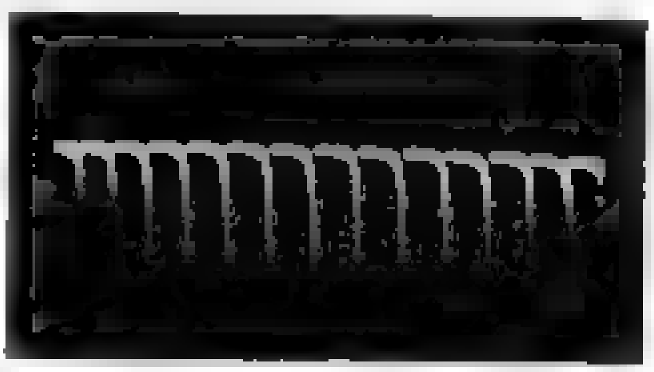


Figure 9. Oscillator output

The tape-step mechanism is of conventional design except that a 2N57 power transistor drives the tape-step magnet. It was mentioned previously that the tape-step magnet was energized for the duration of the rest and start pulse; the addition of the latter interval is necessary for operation at 250 wpm.

A Sigma Series 72 transmitting relay is included as an integral part of the unit and is operated in a polar bridge type circuit so designed that equal marking and spacing currents are supplied to the relay coils.

The unit also contains its own power supply, a special transformer designed for use with two full-wave bridge rectifiers. The core is of Hypersil rather than of ordinary transformer iron in order to save space and weight, and a separate winding of the transformer is provided to excite the tape-reader lamp. The rectifiers used are fused junction germanium diodes.

Conclusion

Because of military design objectives regarding limitations in size and weight requirements, a very compact unit was constructed, as shown in Figures 2 and 3. The socket assembly in the rear of the unit contains the plug-in cards illustrated in Figure 10.

Although the unit was designed to meet peculiar military requirements, the methods and circuits developed for the model of the Transistor Type Transmitter-Distributor are applicable to the development of a commercially feasible model. The present unit indicates the path to be taken when similar equipment is to be transistorized.

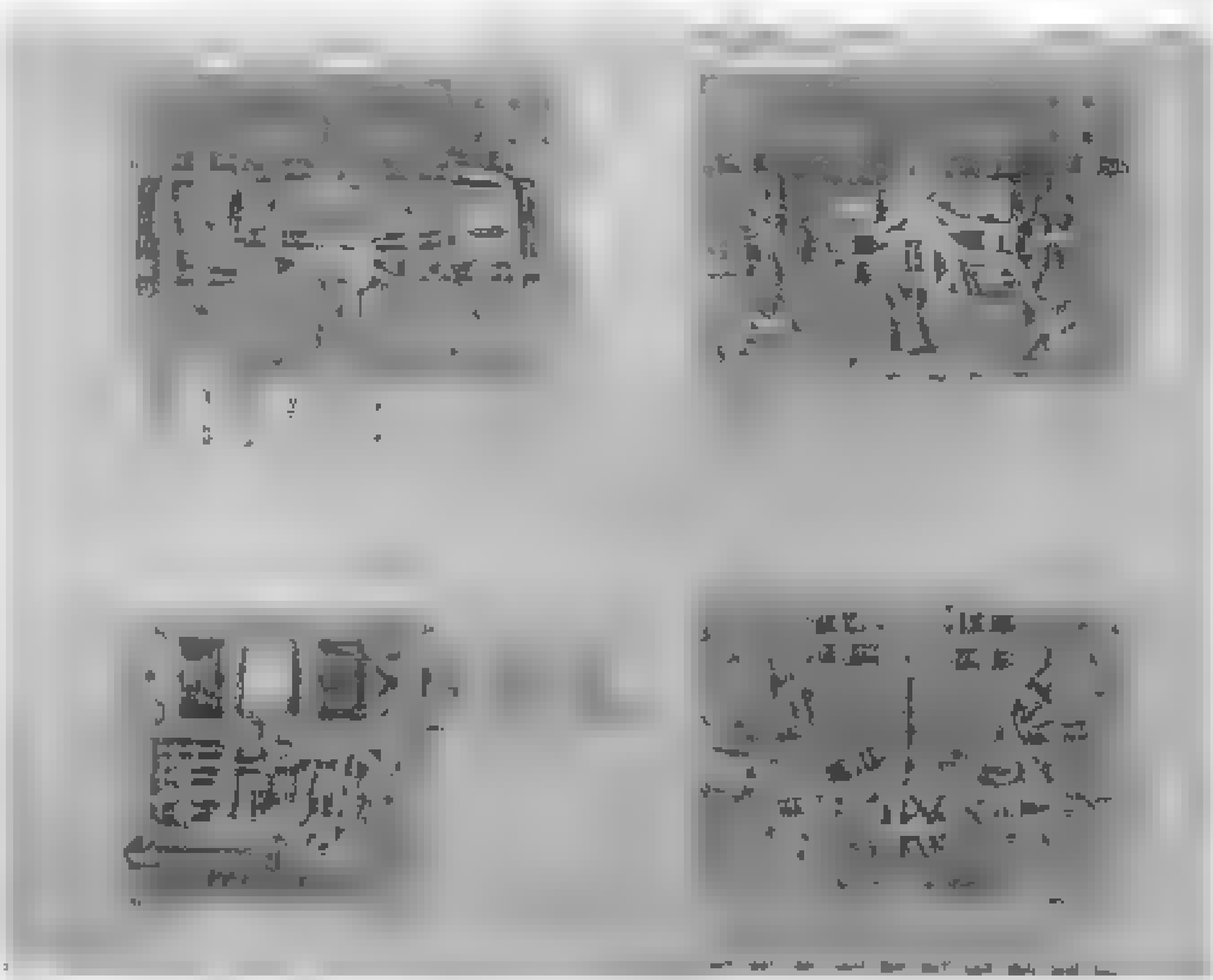


Figure 10. Oscillator and plug-in cards

Upper left—Frequency divider
Lower left—Oscillator
Upper right—Phase advance switch and gates
Lower right—Ring counter drive

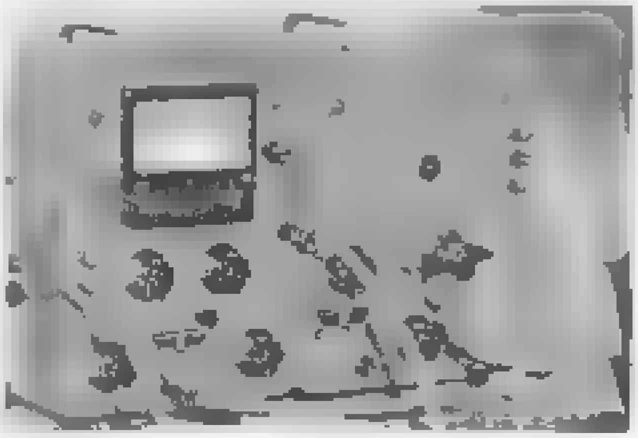
Acknowledgment

The writer wishes to acknowledge his indebtedness to A. E. Frost who headed this project, A. A. Steinmetz and T. E. Melick, project engineers, and H. Harris, engineer.

Howard C. Isaacs graduated from the College of the City of New York June 1949 with a degree of Bachelor of Electrical Engineering and subsequently served with the U S Army in 1950—1952 After release from service, he joined Western Union and was assigned to the Equipment Research Division of the Development and Research Department. He has assisted in an investigation of magnetic storage techniques, development of the Transistor Type Transmitter Distributor development of the TTY Signal Normalizer and now is engaged in further transistor development. Mr Isaacs presently is continuing his engineering studies at the Polytechnic Institute of Brooklyn He is a Member of AIEE.

Transmission Test Set

The small, portable, conventionally styled db meter 3-A has served well for many years It was provided originally when Western Union engineers pioneered the development of FM carrier systems



Today's microwave telegraph transmission measurements are of much broader scope, however than those for which the 3-A meter has been furnished. In this field, the latest instruments to be adopted by the Telegraph Company are Transmission Measuring Set Clough-Brengle 340 (left) and Extended Range Audio Oscillator Clough Brengle 420 (right), shown here. These are commercial instruments modified to meet Western Union Telegraph Company requirements

The transmission test instrument has a balanced input impedance of 135 or 600 ohms to measure dbm levels as low as minus 60 and as high as plus 32 for frequencies from 0.020 to 250 kc. This instrument also has a 10-megohm input impedance for measuring voltages from 0.001 to 300 in the frequency range from 20 cycles to 1 mc. Its arrangement of jacks, switches and pads provides a very convenient transmission test unit. A special jack is provided on the left side to take advantage of the amplifier in the set as a means of driving an external frequency counter Thus the exact frequency of the test tone being transmitted or received is known immediately

The companion oscillator is similar to the transmission set as regards impedances and frequency range and is the same size and weight (about 21 pounds) The planetary friction dial is a special addition to the oscillator which permits setting 150 kc within 10 cps if a frequency counter is available. Normal setting of the dial without the aid of a counter is within 2 percent on high frequencies and much less than that for some of the lower frequencies.—E. R. COSS, Engineer Electronics Applications.

CLELL M. BRENTLINGER, Assistant General Manager, Lake Division

Western Union and the Railroads

"the transfer of the lines of telegraph from the ordinary roads to the margins of the railroads, and the arrangements made for their common employment by the telegraph and railroad companies, is connected with one of the most significant and successful movements of telegraphic history and development." James D. Reid.

EVERYONE who has ridden on a train knows that telegraph wires accompany the railroad lines all over the United States. This is not a mere coincidence, of course. Although Morse operation has all but disappeared from railroad train control, as well as from commercial telegraph operations, it is hard to imagine that the amazing development of American railroads could have taken place without Morse telegraphers to copy train orders, to "OS" trains ("OS" means to report to the dispatcher the passing of a train), and to handle the other details of railroad operation.

Railroad Telegraph Expansion

It is recorded by James D. Reid, in his 894-page historical volume entitled "Telegraph in America", that General Superintendent Minot of the Erie Railroad foresaw the value of the telegraph as a necessary factor in railroad operation over a hundred years ago. He had a telegraph line built along the proposed right of way of new railroad lines even before he closed any construction contracts for track work. Minot first used the telegraph for "dispatching" in 1851, when a train on the newly opened single track Erie Railroad was waiting at a small New York village to meet an opposing train which was running late. Chafing at the delay, Minot thought of the commercial telegraph line along the railway and sent a telegram to the agent at the next station inquiring whether the overdue train had left. Receiving a reply that it had not, the enterprising Superintendent sent a message to the crew ordering that the train not depart until the train on which he was riding had arrived. Thus was sent the first train order. Legend has it that the engineer of Minot's train was not so confident of the reliability of the telegraph, and refused to go contrary to the time table on so flimsy a pretext, whereupon Minot took over and ran the locomotive himself.

Minot's successor, D. C. McCallum, who later became a General in the Union Army in charge of military railroads, made a statement in his annual report to the Erie Board of Directors that he "would rather have a railroad of a single track with the electric telegraph to manage the movement of its trains than a double track without it."

Railroad rights of way offered obvious advantages for the stringing of wires—direct routes cleared and graded through the wilderness, across prairies and over mountains. Too, the physical prominence of the railroads and the operation of trains over their tracks afforded protection to the telegraph wires, as the thundering and hissing locomotives commanded respect which was not inspired by the invisible and noiseless electricity flowing over the unprotected and isolated pole line. The removal of the first transcontinental telegraph line to the railroad right of way largely stopped Indian raids on the lines—thereby no doubt curtailing sharply the supply of bright, shiny wire (and insulator-glass beads) for personal adornment and whatever other uses the primitive Red Men made of wire.

Thus the early railroads, and the telegraph, which eventually came to mean Western Union, grew up together, and still are closely related. In fact some of the old practices have persisted up to the present time. For example, the Magnetic Telegraph Company before 1858 had messengers with blanks and pencils enter the trains during important station stops to

enable passengers to send messages without leaving their seats. One innovation of the same Superintendent of the Magnetic Company, which by the way was later absorbed by Western Union, did not persist very long—that of fining the operators five dollars for each error they made.

Early Railroad Telegraph Contracts

The close relationship of the railroad and telegraph industries necessarily has depended on good will and mutual confidence, but of course the conditions and provisions of the cooperative arrangements had to be formalized in agreements or contracts. One of the very early agreements, which no doubt was so formalized, was made just one hundred years ago, in 1856, between the Pennsylvania Railroad and the Pennsylvania Telegraph Company, a subsidiary of the Mississippi Valley Printing Telegraph Company. The telegraph company, to quote Reid,

> adroitly suggested to the railroad company that it would be of vast importance to them to have a special line of telegraph which would be worked by such machinery that no information sent by it could be taken off en-route, the machinery to be placed only in the chief offices of the company. It was also intimated that a sublime machine of this character could be obtained without cost to the company, upon the terms of a simple grant of permission to erect a wire upon the poles of the railroad company."

Charles Minot, general superintendent of New York and Erie Railroad, in 1851 issued the first train order by Morse telegraph. A monument to honor Minot and commemorate his act was erected by Railway Telegraph Superintendents and Telegraphers.

In return for this "machinery" the railroad granted what perhaps was the first agreement for contact (i.e., pole line) occupancy. Continuing the quotation:

"In token of gratitude, they gave the agent of the new company not only the right to put a wire on their poles and to occupy one end of their cross-arms, to be worked for use of himself and assigns, but they agreed to maintain the poles and arms, to instruct the repairers of their own wire to repair both—the telegraph company to furnish the wire and insulators. The railroad company also provided that the telegraph company should have a hand-car, and such other facilities as the Superintendent might provide; agreed to carry all persons, material, etc., and to give them the use of the railroad wire when the wire of the new company was out of order. All that was asked in return for these liberal grants was simply that the new telegraph company should erect a good galvanized wire of good size for its own use, put printing instruments at Philadelphia,

Lancaster, Harrisburg and Pittsburg, and give the railroad company the free use of it in sending railroad messages when necessary, and to have the right to its sole and private use for private correspondence, but not longer than fifteen minutes at a time. Is there any thing lovelier recorded in the histories of human affection?"

Such contracts, perhaps with less evidence of human affection but nevertheless with mutual confidence, are in effect between Western Union and almost every railroad in the land, from the giants as represented by the Pennsylvania or Santa Fe to the numerous "short lines," many of which are only a few miles in length, and one indeed is only three miles long. Surprisingly, some contracts are with railroads with no mileage—railroads that were never built; the plans did not materialize and the contracts are without substance.

First telegraphic train order was sent from this station at Turner, N. Y., (now Harriman)

Credit for much of the early accomplishment of contract arrangements is given to Illinois Supreme Court Justice J. D. Caton, who apparently by coincidence or accident was drawn into the highly competitive picture of commercial telegraphy in the early 1850's, and who, realizing both the need and the opportunity, became a leader in putting the infant industry on its very shaky and uncertain feet. His activities as regard contracts interest us here, although the Judge was active in all phases of the problems of the wire companies.

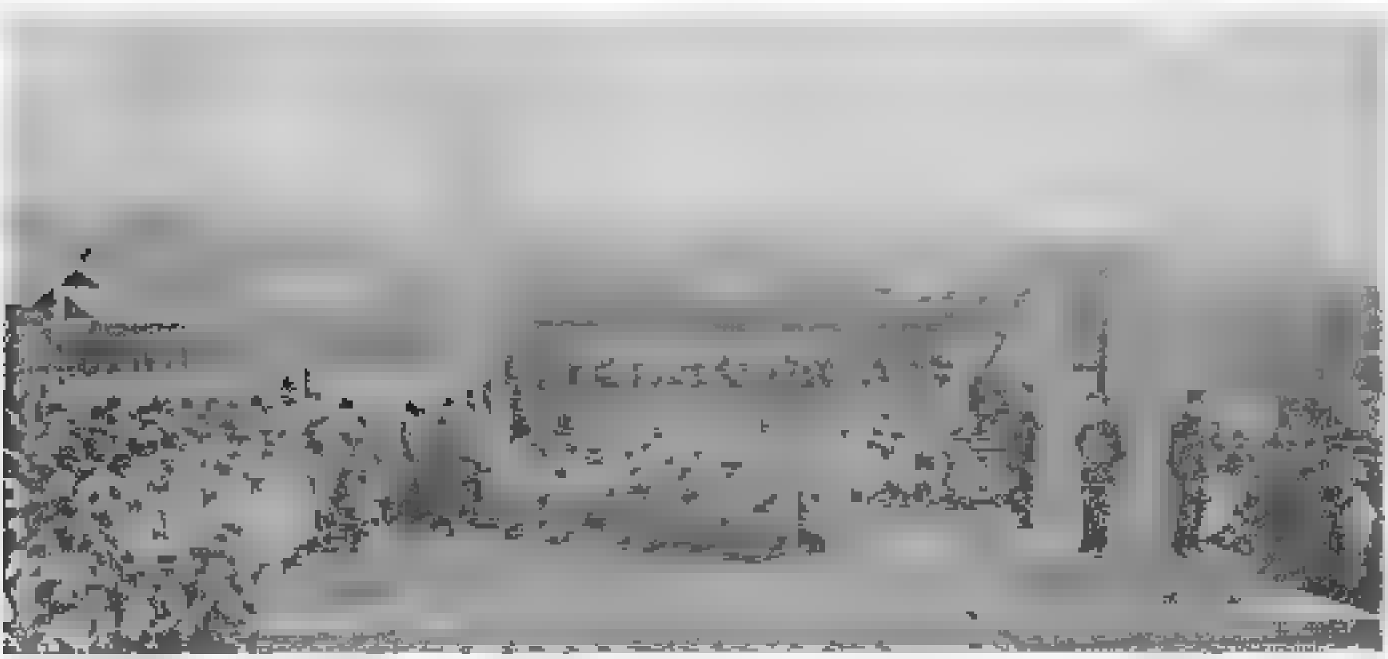
His agreements with railroads, dating from 1855, included such important features as—again quoting Reid:

"1. The recognition of the structure as the property of the telegraph company.

"2. The recognition of the railroad to the right of priority and free transmission.

"3. The manning of the offices by the railroad company, under the absolute control of the telegraph company, and the division, on a certain just basis, of the receipts for commercial messages.

"4. The payment, by the railroad company, of $30 per mile for removal of existing lines on the railroad, and $100 per mile for the construction of new line.



Dedication at Harriman, N. Y., May 2, 1912, of bronze tablet to commemorate start of train dispatching by telegraph

"5. It provided for the free transportation of material needed for construction and repairs.

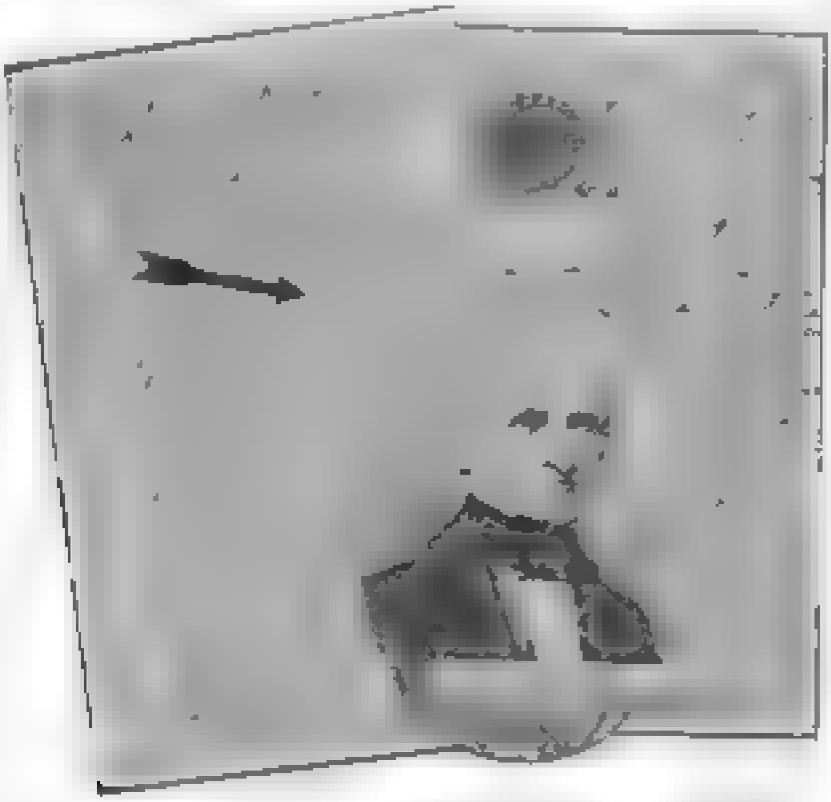
"One of these earliest contracts, for running trains by telegraph, was made in 1856, with Governor Matteson, President of the Chicago, Alton and St. Louis railroad. In connection therewith, Judge Caton arranged for President Matteson a night service, appointed a night and day superintendence of the service at Bloomington, to whom all trains reported, and who had authority to move them. The night watchmen at the stations where continuous night telegraph service was not demanded, were ordered to call operators at any hour of the night when a train was fifteen minutes late."

Later Railroad Contracts

Modern contracts are written and executed by Western Union's Director of Contracts, and signed also by a proper official of the railroad concerned. There are at present some 150 such railroad contracts, approximately equally divided into two general classifications. In one category are those with roads on whose rights of way Western Union owns pole lines; in the other group the railroads own the pole lines.

Perhaps the major item in the contracts is that which governs the building, maintenance, and use of the wires. These and other provisions cover such points as: rates for attaching wires of one company to the poles of the other; charges for occupation by Western Union of the railroad's right of way—in other words, rental for ground occupied by poles, guy wire anchors, and so forth; rates for the leasing of single wires, pairs, aerial or underground cable, and equipped telegraph or carrier channels; the cost of labor and material for work done on the pole lines; and other "plant" matters—even to the arrangements for operating hand and motor cars and work trains on the railroad's tracks.

Liability for accidents is an important



Former postmaster general Amos Kendall became Morse's agent to organize the Magnetic Telegraph Co. to build the first line from New York to Baltimore and Washington. By the agreement shown here in part, The Washington and New Orleans Telegraph Co. and the Magnetic Co. were merged with the American Telegraph Co., which agreed to assume all obligations in contracts with railroads.

feature. Even if no one is hurt in a collision between railroad and Western Union equipment, the property damage may be extensive. Recollection of an accident report filed by a train conductor, which the writer transmitted while working as a railroad telegrapher many years ago, still evokes a smile. An old time Western Union lineman named Joe Metcalf was barreling along on his motor car over a single-track railway and forgot to watch the timetable. The result, when Joe met a freight train on a curve, was described in the conductor's accident report somewhat as follows

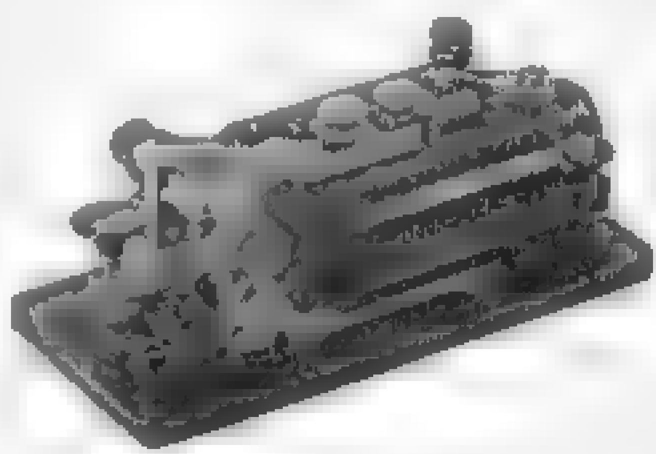
"Injuries to personnel: none (Joe had jumped—just in time) Damage to equipment: to my train, none; damaged Joe Metcalf's motor car to fullest extent."

Another important item is found in the sections of the contract which specify the conditions under which the railroad station agents act as Western Union's representatives in dealing with the public, accepting outgoing messages over the counter and sending them to the proper relay office on the one hand, and on the other receiving incoming messages from the relay office and delivering them to the addressees. The contracts specify the commission and other charges paid to the railroads for the work involved, by various patterns of accounting procedure

The liability of the railroads for any errors or service failures caused by railroad employees is disclaimed in the contracts, since the railroad employee is acting as an agent. Likewise the contracts cover access to railroad stations by Western Union patrons, and disclaim liability in that direction. Recently a man driving through a small Midwest town stopped at the depot to send a telegram. While he was writing and filing his message the ticket window fell on and injured his hand. Since he was a Western Union customer, the Telegraph Company bore the medical expense even though the railroad owned the ticket window

Older agreements between railroads and the telegraph companies also provided for an exchange of services whereby the railroad carried freight for Western Union, without billing and furnished passes for Western Union people traveling on company business. In return the telegraph company handled the railroad's telegrams and furnished dispatchers' and message circuits to the railroad. Later agreements provide for tallies and settlement for services exchanged, on an equitable basis, or in many cases for cash payment for telegrams, freight, telegraph circuits and passenger transportation

Some of the existing contracts are very old, having been amended as necessity arose. The "agreement" with one major railway system actually consists of almost 50 separate documents, the oldest of which dates back to 1869. One of the sections covers the sale, for two dollars, of one telegraph pole to the railway, "to have and to hold the same unto the second party, its successors and assigns to and for their use and behoof forever."



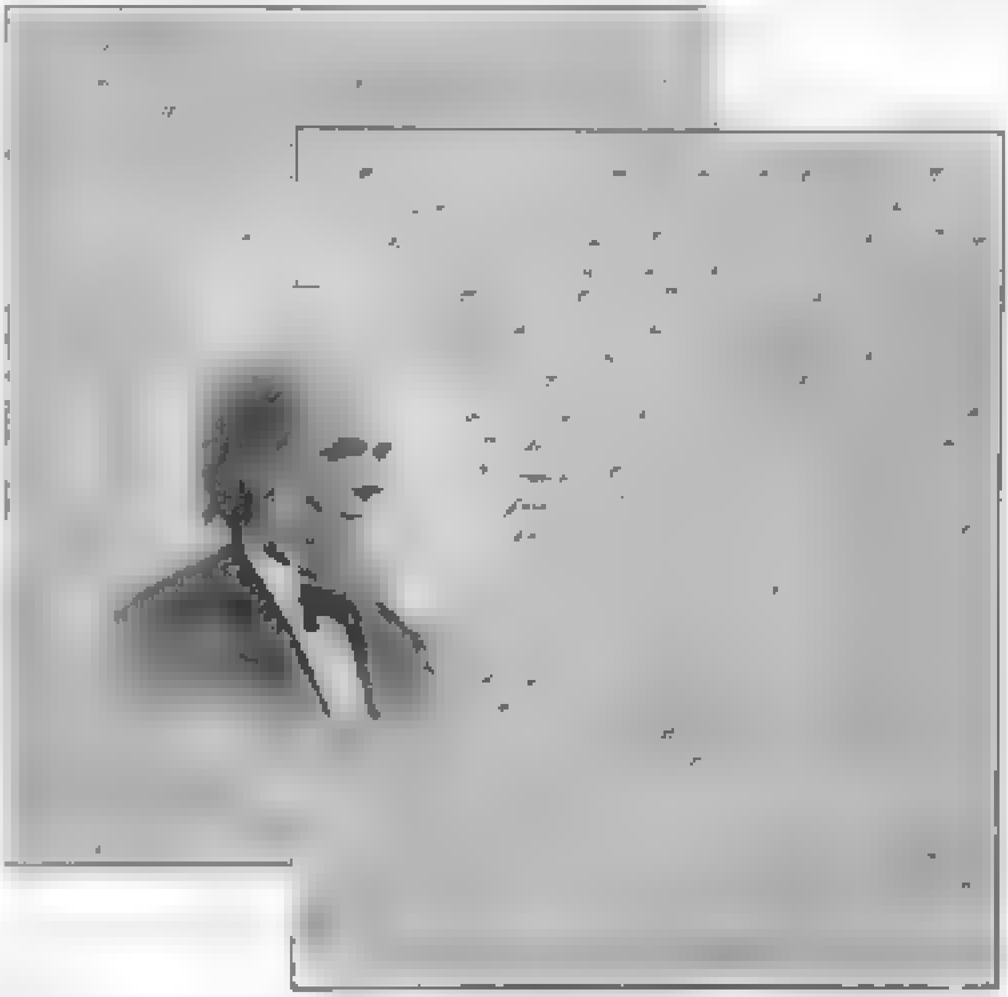
Pocket telegraph set carried in leather case by trainmen and linemen in Morse era

This same contract for many years contained a provision whereby Western Union was required to teach Morse operation to conductors, engineers, firemen and brakemen comprising the train crews, so they could, in case of a train wreck in an isolated spot, climb a nearby telegraph pole, and with a special instrument cut in on a wire and ask for help. There is no record of any success attained in teaching Morse to train crews.

Joint Administration of Contracts

Administration of joint contracts on behalf of Western Union is a responsibility of the General Manager of the Division in

whose territory the railroad has its general headquarters. Administration on behalf of the railroad may be in the hands of the operating officer or chief engineer, but generally the day-to-day administration of the contract, and the relations between the two companies in general, are delegated to a "Joint Superintendent" who may receive a part of his salary from each company. This joint employee is equally responsible to the two companies



Jeptha H. Wade and the 1856 contract with the Pennsylvania Railroad the original of which is among Western Union records. In addition to a new wire, Wade agreed "to furnish House Printing Telegraph Instruments" and to send railroad messages free of charge.

for the protection of their interests, and it may be said to the credit of a long succession of Superintendents that their fair and impartial efforts "to serve two masters" have been successful. It can also be said that harmony has existed in those cases where the officer in charge of communications is paid by and technically is responsible only to the railroad company. Thus the relationship of Western Union with the railroads has been a very satisfactory one.

Problems common to the railroads and Western Union ordinarily are solved by the Superintendents of Communication and the General Managers, respectively, but differences of opinion can and have arisen on policy matters or contract interpretation, so most railroad contracts provide for arbitration of unresolved differences of intent and interpretation. In fact, however, arbitration cases are very rare. As is provided in most arbitration agreements, each party chooses an arbitrator, and the two thus selected agree on a third member of the board. Should the two find themselves unable to agree on the "neutral" member, a court judge is requested to make the selection.

Some of the administrative problems that arise are very intricate, and might confuse even an arbitration board, if unfortunately they were to reach that stage. In one case a certain railway, when moving its tracks for highway construc-

tion through a small city, found a pole line carrying a substantial number of wires on its right of way, in addition to the line carrying its own wires and shown on its drawings. This railway line paralleled the tracks of another major line at this point, and the latter's tracks were jointly occupied by its own trains and those of a third railroad, under a lease. It seems the newly discovered pole line had been built, many years ago, by one of Western Union's merged telegraph companies, under an oral agreement, perhaps based on a contract dating back to Civil War times, the contract being with the "third" road above, which was without tracks and occupying those of the paralleling road, the situation being complicated by the fact that the pole line wasn't even on the property of the lessor, but on the right of way of the innocent bystander. Such a situation can be, and almost always is, resolved by agreement between the parties concerned.

Expanding Communication Technology

The continuing cooperative attitude of Western Union and railroad managements toward each other in technical matters is indicated by the participation of Telegraph Company engineers and staff men in the activities of the Communications Section of the Association of American Railroads. This organization consists of the communications officers of all the railroads, and its purpose is to develop and adapt new ideas for the benefit of railway operation. The A.A.R. functions through committees dealing with the various phases of communication, and Western Union engineers and other representatives serve regularly on these committees, to the mutual advantage of both telegraph and railway companies.

In fact, it might be said that the A.A.R. is the principal meeting place of the railroads and the communication industry. While the problems of the individual railroads vary according to conditions and circumstances, the basic requirements are common to all, and it would of course be not only absurd but impossible for an individual road to develop its communication system from the ground up. All the technical advances of Western Union engineers, and of other organizations as well, have been available through the A.A.R. to the Superintendents of Communications, and these men, through individual effort as well as collectively, have made amazing progress in furnishing their managements with one of the most vital components of modern transportation.

Present railway communication systems are as far ahead of those of fifty years ago as the Telegraph Company's reperforation

Judge J. D. Caton whose energetic administration of the Illinois and Mississippi Telegraph Co. made it highly successful

system is ahead of Morse relay. Manual Morse has virtually been replaced on many roads. The present-day superintendent of communication, whatever his precise title, has responsibilities which have expanded commensurately with the broadening of communication bandwidths. Through the use of carrier equipment now available from several manufacturing suppliers, new frequency channels for the handling of low-cost teleprinter and telephone traffic have been widely derived throughout the railroad industry. Selec-

tion and switching of printer drops for individual and multiple-outlet telegraph transmissions parallel priority and storage practices on the telegraph company's private wire systems. Western Union facsimile has entered the transportation picture in connection with Ticketfax and other forms of reservation service, as has Teleregister, a former Western Union subsidiary Radio microwave relay, in which the Telegraph Company pioneered, has been adopted to supplement pole lines by certain railroads having high levels of traffic density In many cases the carrier facilities carried on the beam accommodate teleprinter and voice circuits. Exploratory moves have been instituted in data transmission for centralized railroad administrative control

Separate passenger and freight frequency channels on radio and "wired wireless," or track and pole-line inductive systems have entered the railroad picture in many applications. A train can be identified by the pattern of its inductive "kick". As a safety measure, the train can be electronically slowed or stopped. It is now commonplace for locomotive engineers and freight and passenger conductors to converse with each other by telephone throughout the length of the train, and for them to converse with crews on passing and other trains and with switch towers; and to take orders enroute from dispatchers and yardmasters throughout the territory of train operations. The making up of freight trains by switching crews and operators in classification yards has been revolutionized by radio and telephone practices; these involve portable dial telephones, strategically located cut-in jacks speaking posts, yard loud speakers and talk-back systems, radio "walkie-talkie" and even closed-circuit television for safety inspection and the recording of car numbers.

The provision and maintenance of all this electrical equipment and associated pole-line and underground circuitry is a major concern of modern joint superintendents of railroad communication, whose responsibility has increased as the methodology, the extent of the equipment, and the corresponding capabilities of the electrical personnel have broadened Behind it all is the heritage of a telegraphic past, and a continuation of the old spirit of cooperation, in which the railroads and the telegraph grew up together, —in spite of the complexities of telegraph carriers, printers, facsimile circuits, and all the other modern developments which make for progress, but probably at the expense of tranquillity and peace of mind.

Bibliography

The following bibliography of railroad telecommunication covers the principal topics of modern practice. The list of railroad systems, however, is not complete, and it will be supplemented two issues hence by any addenda brought to the attention of the Secretary of the Western Union TECHNICAL REVIEW by correspondence, if initiated before April 1 1956

Unless otherwise credited, all references are to the designated issues of WIRE AND RADIO COMMUNICATIONS or, before July 1953, to its predecessor TELEGRAPH AND TELEPHONE AGE.

ALASKA
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System, July 1948, p. 18.
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CANADIAN NATIONAL
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Yard Speaker, January 1950, p. 10
Radio, June 1954, p. 10

NATIONAL RAILWAYS OF MEXICO
System, February 1951, p. 7

NEW HAVEN
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NEW YORK CENTRAL
Teletype, August [illegible], p. [illegible]
Telephone, October 1949, p. 3
Terminal, May 1953, p. 10

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Freight Radio, August 1949, p. 6
Yard Speakers, January 1952, p. 10

NORTHERN PACIFIC
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Radio, June 1952, p. 6
Teleprinter, August 1953, p. 14

PENNSYLVANIA
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Car Clearances, Television, May 1954, p. [illegible]

QUEBEC NORTH SHORE & LABRADOR
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READING
Radio, September 1953, p. 12

ROCK ISLAND
System, October 1953, p. 15; May 1955, [illegible]
Freight Radio, June 1953, p. 12
Television, October 1955, p. 10

SANTA FE
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SOUTHERN
System, September 1948, p. 8
Yard Installation, December 1951, p. 12

UNION PACIFIC
Employee Training, February 1954, p. 11

GENERAL

Train Orders by Facsimile Telegraphy, J. H. HACKENBERG [illegible] R. DEACS, Electrical Communication [illegible]

A Modern Cab Signaling and Train Control System [illegible] R[illegible] Trans. AIEE vol. [illegible], Part [illegible], 1951, pp. 232-9. (Note—Pennsylvania and Seaboard Air Line)

Public Train Passenger Radiotelephone Service, N. MONK [illegible] Proceedings, October [illegible] p. [illegible]

Electronic Line Multiplier, G. D. POOLE, *AAR Communications Section Proceedings*, October 1952, p. 465 [illegible]

[illegible]-ticker-to-Train Radio Communication System, F. L. [illegible] AAR Communications Section Proceedings [illegible]

Railroad Microwave Installations [illegible] R. [illegible] *AAR* [illegible] Proceedings [illegible] p. [illegible] [illegible] Santa Fe

Microwave as Applied to Railroad Operation in the Gulf [illegible] Trans. AIEE vol. [illegible] Part I, 1953, pp. 400-3. (Note—Santa Fe

Railroad Communications Using High Power Carrier Techniques [illegible] HANSEN, W. W. H. DEAN, T. G. [illegible] 1953, pp. [illegible] (Note—Quebec North Shore & Labrador)

[illegible] Railroad Communications [illegible] T. H. [illegible] R[illegible] *and Radio Communications*, August 1954, p. 14

[illegible] to Line-reading [illegible] Communications, June [illegible], p. [illegible] (Note—[illegible] Shore & [illegible])

[illegible] of American Railroads Report to United [illegible] and Radio Communications, February [illegible] p. [illegible]

Cloll M. Brentlinger became a Morse telegrapher while attending high school at Carlisle, Indiana, and worked for a time as an operator for the Evansville and Terre Haute, Frisco and Chicago and Eastern Illinois Railway Companies. He was graduated from the University of Illinois with the degree of B.S. in E.E. and joined Western Union immediately thereafter. He has occupied the positions of Engineering Assistant, General Inspector, General Traffic Supervisor, Division Traffic Superintendent of the Central and Lake Divisions, and General Superintendent of Traffic, and is now Assistant General Manager of the Lake Division. While on the staff of the Vice President in charge of Traffic, Mr. Brentlinger was for a few years concerned with submarine cable operation, and was active in the testing and introduction of tape printers to replace the page printers originally used on Multiplex trunk circuits, and in the trials and adoption of teleprinters. He now is primarily concerned with railroad contract matters, employee relations, and budgets and forecasts. He is a member of Eta Kappa Nu, a member for life of AIEE, and served a three-year term as a member of the Board of Directors of the National Electronics Conference.

ROBERT W. HARRIS, Assistant to Systems Planning Engineer

Keyboard Standardization

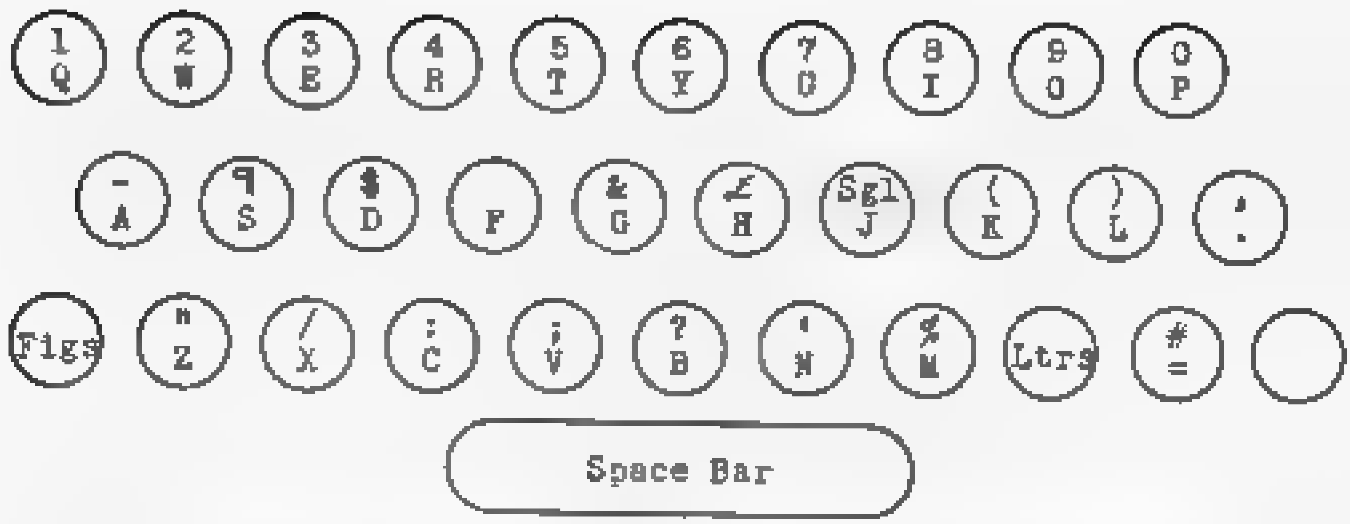
In this country page teleprinters ushered in a new era of printing telegraphy following World War I; then, during the 1920s, a complete transition to tape teleprinters was effected. In recent years, Western Union has employed hundreds of page machines in special situations but now, in 1956, the company is about to revert to page reception in a large segment of public communications. How keyboard standardization makes this more practicable, how page and tape will work together for faster, more efficient terminal handling, the ingenious control equipment and the new look in sprocket feed page printers, is discussed. The modified teleprinter with its message safeguards and automatic number check, and the control equipment for sending positions, manual and automatic, have been developed and placed in trial service. Implementation of these developments through page receiving installations in major offices will follow. Meanwhile, the initial teleprinter keyboard conversion program, involving only tape teleprinters, and perforators working with reperforator centers (about [illegible]0,000 units), has been virtually completed.

For nearly four decades high-speed record communications have depended primarily on printing telegraph. Other methods have been developed and successfully applied to supplementary services, but it is safe to say that, despite the rapid growth of facsimile telegraphs, permutation coded printing telegraph will remain the backbone of the telegraph industry for many years. Printing telegraphy in the U.S.A. has taken great forward strides since the mid-thirties through development of reperforation techniques and their application to the public message system. Manual reception and retransmission at relay points have been eliminated by the establishment of major reperforation centers, greatly improving the speed and efficiency of telegraph service. At destination points, however, all those messages on which physical delivery is required must be processed manually to produce a Western Union telegram.

Quite generally today the yellow blank familiar to millions carries its message on printed tape secured to it by adhesive and more than 300 million feet of the gummed tape were required last year to serve the nation's business and social communications needs. Obviously, if these messages were received on page printers the time required for tape gumming would be eliminated, a fact recognized as far back as 1915 when printing telegraphy was introduced widely into the Western Union system, on a page-printer basis.

Tape teleprinter was designed to meet Western Union specifications

To those familiar with telegraph problems, the conversion from the page to the tape method which took place in the early twenties might appear unwise. The decision was reached, however, only after thorough study and analysis of operating problems. Inherent in the tape method is the ease with which corrections may be transmitted and applied to the received copy as "paste-overs" thus avoiding "reruns", the elimination of the line signals required for the carriage functions, and lower first cost and maintenance of equip-



Keyboard arrangement used many years with tape teleprinters, which needed no carriage-return or line-feed functions. Keys S, F, ( ) N, M, were unlike page teleprinter keys.

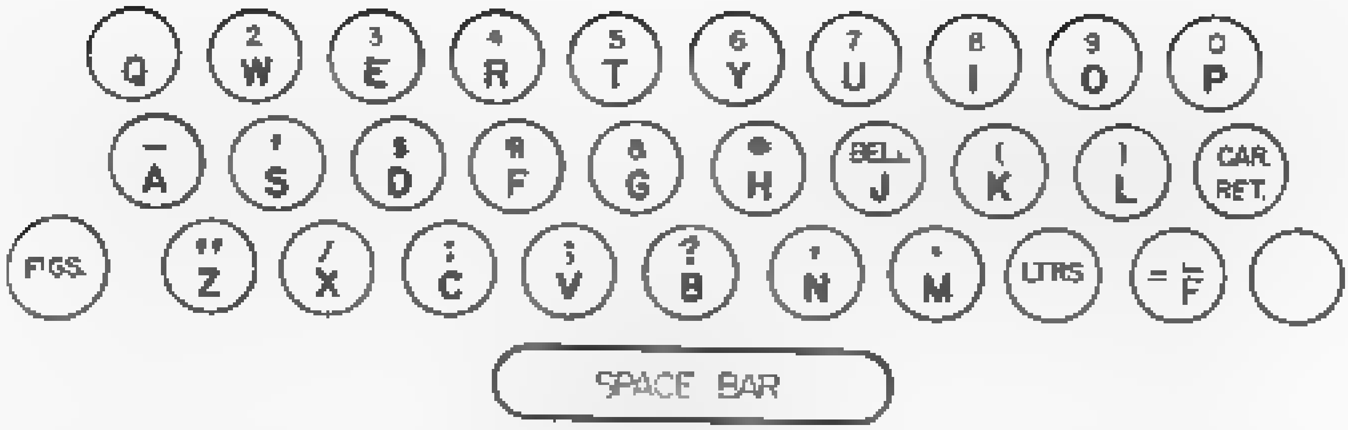
ment. These factors all contributed to the decision to replace the early and less perfected page printers with tape machines.

Technological advances in equipment, circuitry and especially transmission and concurrent changes in operating practices over the past 30 years, however, have brought about a reversal of the relative positions of the tape and page teleprinter for circuit termination. Use of carrier circuits with improved means for multiplex synchronization largely eliminated errors resulting from line hits common on open line grounded wire circuits. With the excessive unproductive time required for "reruns" thus minimized, the page printer is destined again to play an important role in the company's communications system, as a receiver-only for many single trunk circuits and for groups of trunks operating on an unattended basis. The transition from tape to page is an important step forward in better record communications and it has involved many problems that have been satisfactorily solved.

A major problem of very wide scope in the transition from tape to page lay in the dissimilarity of the keyboards of the two types of teleprinters. These differences, mostly in upper-case characters, may be explained by the fact that code combinations affecting the carriage-return and line-feed functions were not needed for tape operation and could therefore be used for additional characters, including a "tape cut" signal to guide the receiving operator. Thus some improvement in operator production, both sending and receiving, as well as reduced line time, resulted from the rearrangement from the original page to the tape keyboard.

The need for systemwide compatibility of all teleprinter keyboards—which, incidentally, do not include any small roman letters—became apparent with the introduction of page printers for customers' tie lines and particularly following consummation of the Postal-Western Union merger in 1943. Interchange of traffic between teleprinters with nonmatching keyboards depended on a one-way tape-to-page translator or manual retransmission. As a first step toward keyboard standardization all Postal Type 14 tape printers were converted to Western Union tape standard. Further standardization to effect conformity between tape and page was then studied by an interdepartmental committee.

The findings of the committee stressed the urgency of making a systemwide conversion of keyboards to facilitate expansion of reperforator switching into the tie-line field and to permit exploitation of page-printer reception on public message circuits. The keyboard layout recommend was essentially a Western Union page type with bell signal on "J" but included a "¶" on upper case "F". The purpose of "¶" is to facilitate original "punching" of tape on perforator or tape teleprinter keyboards, and ensure recognition of the paragraph on messages



New standard key layout eliminates £ and %, places ¶ on upper-case F on tape keyboards, and ('), #, (.), (,), in same positions on both tape and page keyboards. Blank key perforates feed holes

received on tape printers. *Since tape or page reception of messages originating on page teleprinters is not facilitated by "¶" this character will not be installed on existing page printers.*

Conversion of teleprinter keyboards at first posed a difficult problem. Since compatibility must be maintained continuously and even temporary impairment of the service cannot be tolerated, it appeared that keyboard conversion would have to be carried out in its entirety over a relatively short period. The first plan contemplated keyboard conversion at all functional offices including reperforator centers during a Saturday-Sunday period, tributary circuits over a 90-day period, and manual circuits as rapidly as circumstances permitted. During conversion, operators were to be required to send "PAR" for "¶", "APOS" for (') and "NBR SIGN" for "#". Tie-line switching was to be discontinued until tributary offices all were converted. With some 35,000 printers involved, the cost of this conversion program and the labor and operational difficulties entailed led naturally to a careful consideration of all possible alternatives.

Further study developed a practicable *modus operandi* for converting, and only the 10,000 units associated directly with the reperforator system were included in the standardization. The conversion extended over a period of about a year and the work was divided into two distinct steps. Use of certain upper-case characters was discontinued so that converted and unconverted keyboards could work together indiscriminately. After the changes had been effected on all equipment involved, the upper-case characters were used in their new locations, thus making the old locations available for installing the remaining slugs to complete the conversion. The first step comprised the following changes:

Present			Proposed		
Lower Case		Upper Case	Lower Case		Upper Case
F	—	Blank	F	—	¶
H	—	£	H	—	#
M	—	%	M	—	
S	—	¶	S	—	'

Temporary stick-on key cap covers were provided for use during the conversion stage. The temporary covers for the letters F, H, M and S showed no upper case characters. Paragraph was punched "— 5 spaces."

The second stage comprised the following changes:

Present			Proposed		
Lower Case		Upper Case	Lower Case		Upper Case
N	—	'	N	—	,
–	—	#	–	—	_

Since all key cap changes were made during the first conversion step, it was necessary to provide temporary key cap covers to show the old markings for the N, period and equals sign keys. Stick-on key cap covers showing upper-case N-blank replaced the first temporary key cap covers showing upper-case apostrophe ('), during the second stage of the conversion period.

Implementation of the recommendations of the committee followed formulation of

a method for unattended page-printer operation. Very real savings were forecast for this project of which keyboard standardization constituted a first and important step. Some serious problems in addition to keyboard standardization per se were presented in the related development of unattended page-printer operation and "From Tie-Line" page-printer switching.

Decision on an over-all operating method was prerequisite to inauguration of the keyboard conversion program. There is a common misconception of operation of mixed tape and page printers with standard keyboards. A "tape" originating message cannot be received on a page teleprinter unless the message has been prepared in anticipation of such reception by a character count and insertion of carriage-return and line-feed signals whereever needed. This is because automatic carriage return and line feed is not practicable on any *standard* page printer. Due to the inertia of the carriage the travel time for a full line is in excess of the time to send one character (space), and even with a short line, dash-pot operation with attendant carriage "bounce" produces an irregular left margin.

Page-printer control unit at the sending end

Because of this situation, two alternative solutions were weighed, i.e., preparing all messages with carriage returns and line feeds or introducing these functions automatically at the point of direct transmission to the receiving page printer. The latter plan was adopted to save operating labor and to reduce the possibility of human error. Increased operator "punching" time of about eight percent was forecast with original preparation in page form and, because the major portion of Western Union's traffic flows through a reperforator center which places the sending and receiving ends out of direct contact, any failure by the sending operator to punch "CR" (carriage return) or "LF" (line feed) would result in an undeliverable or undecipherable message. In addition, all originating points would require character counters, to ensure proper length lines on messages received on page printers. These have a character spacing of 10 letters to the inch instead of the 8-to-the-inch spacing which is standard on tape machines. Again, necessity for counting lines would place a further burden on the operator punching tape at the point of origin. The received copy would still not be produced in the preferred form for delivery which requires that the identifying number appear at the beginning of the "top" line, and long message reception would involve a difficult problem. Thus it will be appreciated that development of the page-printer control unit at the sending end was an essential part of the keyboard standardization — page printer program.

Attention was next directed to the teleprinter. Unattended page-printer reception to produce deliverable copies introduced new problems. Page-printer application had been limited to tie-line operation where message form, physical delivery, or retransmission by Telefax were not considerations. The first problem lay in automatically separating individual telegrams made on a continuous paper supply, either rolls or fanfold. The first effort contemplated using customers stand-

ard side-printed 5-inch rolls. The laboratories developed an automatic knife which responded to a signal sent at the end of transmission of intelligence. The cutoff point was arranged to produce a sheet of one, two or more standard message lengths.

There are inherent weaknesses in roll paper for public message service. Besides the disadvantage of having a variety of lengths of blanks, platen slippage, an uncontrollable variable, produced variations in these "standard" length sheets. While side-masthead paper was satisfactory for tie lines, Western Union naturally

Final key caps were furnished in sheets as semi-punched discs showing white letters. Part of a sheet is shown

preferred to use its long established and widely advertised standard receiving blank. Also there was a problem with paper curling at the interior of the roll, which interfered with intra-office message transit on belt conveyors. It was obvious that the new application for page printers demanded a new approach printerwise.

Consideration was then given to so-called fanfold margin-punched perforated paper and sprocket-feed printers. It was found practicable to design a message separator, employing principles embodied in commercial "bursters", which could be attached to the printer cover. By reducing line spacing from three to four lines to the inch, several important objectives were gained. Platen circumference of 5½ inches matched the standard 5½-inch commercial form punched paper, an even multiple of ¼-inch line separation. Thus the "burster" motor could be triggered by platen mounted contacts. Utilization of standard spaced perforations meant large savings in cost of paper message forms because manufacturing equipment is available for volume production of such forms. A further advantage of four lines to the inch lies in reduced paper area for any given quantity of intelligence. Thus scanning time is reduced on messages for Telefax terminal handling.

Because printers will be operated in groups entirely unattended except for editing the received copy at a single editing RQ and routing position, new safeguards were needed. Operating requirements established the following minima which were successfully developed:

1. The call letters and sequence number of each message should be checked.
2. Assurance should be given that a piece of paper comes out of the printer for each message number checked.
3. Each piece of paper should bear an identification showing the printer from which it was ejected.
4. The platen and paper must be in register with respect to the heading.
5. Failure to meet any of the above requirements shall de-activate the received number indicator and bring up an alarm. The message involved plus all ensuing messages should be held at the teleprinter until manually checked and released.

The page-printer control unit was a collateral development with the printer modification. This equipment, consisting of three relay banks and one relay-and-rotary switch bank, is associated with the line sending position at the reperforator or manual office. It controls the transmitter, reads the tape fed to it and generates appropriate CR-LF signals.

Sequence of operation is as follows: When the first intelligence in the tape is encountered at the transmitter pins, the transmitter is stopped and time and date requested. A standard "chronitor" transmits time and date directly to line and the tape is started. The control unit then reads the tape to detect the identifying number which always follows automatic numbers, and sends CR-LF so that the identifying number will appear at the beginning of the second line. Equals signs which follow filing time, name to, destination, body and signature are converted to CR-LF to produce a message in orthodox form for physical delivery. Carriage return-line feeds required for the body of

the message are generated following a character count of each line. The number of characters (excluding Figures, Letters and Blanks) in each line are counted on a rotary switch, and CR-LF is inserted following the first space character encountered after 58 characters have been tallied. If a space does not occur by the time 70 characters are counted, CR-LF will be inserted following the 70th character. This prevents piling up at the end of a line.

Whenever a CR character is read in the tape, the following character is examined and if it is not a LF, a LF is generated and transmitted to line. Fortuitous occurrence of CR would otherwise cause overlining on the received printer copy. If a CR-LF combination is read at the end of the top line, the message is identified as originating on a page printer and passed to the receiving teleprinter per copy. Paragraph sign is converted into CR-LF five spaces.

All message lines are counted and at the end-of-message signal (CR-CR), line feeds are generated so that a total of 22 will be transmitted to line to advance the paper into registration, for receipt of the next message. If CR-CR is not encountered before 16 lines are tallied (a long message), transmission of the message is momentarily stopped and sufficient line feeds are transmitted to register the paper correctly for the second sheet. Thus all long messages are contained on multiples of the standard size form.

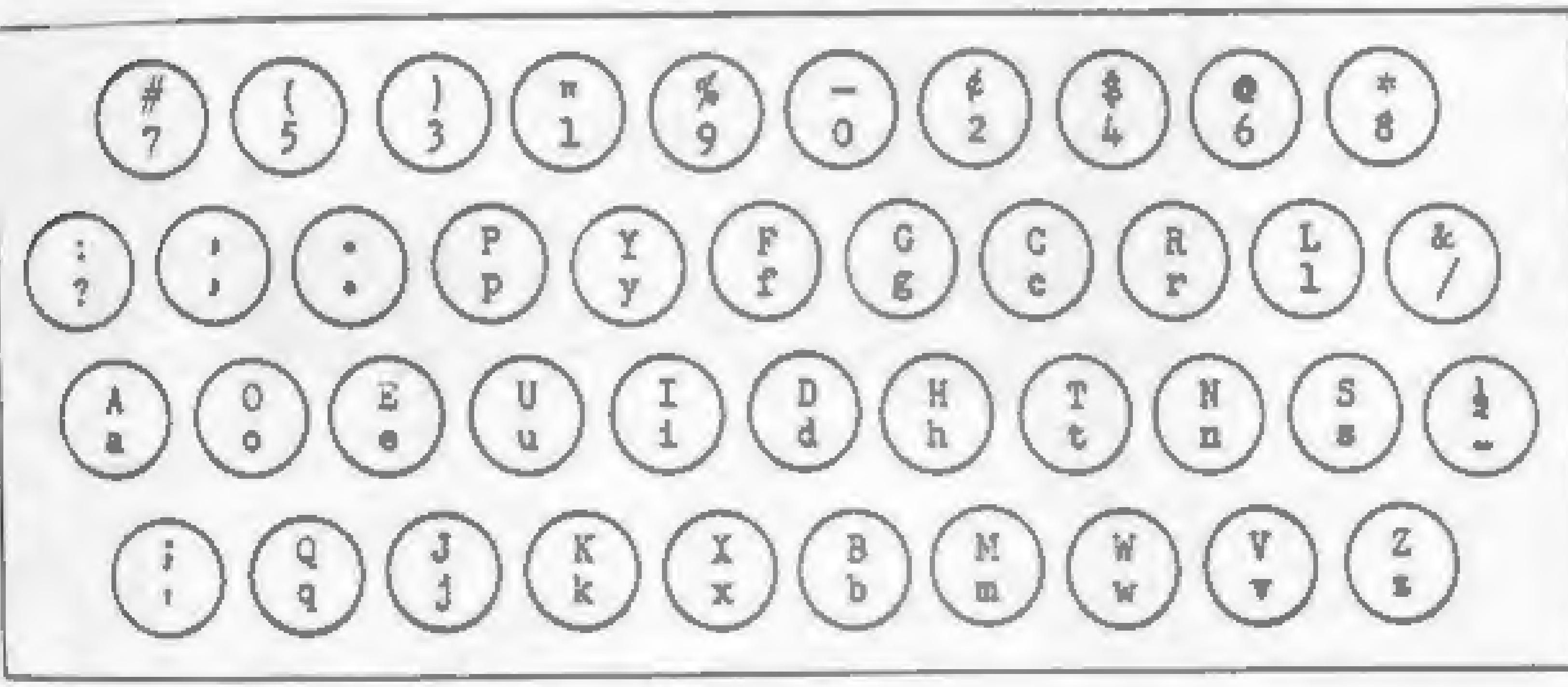
Application of sprocket-feed burster-

Sprocket-feed, "burster" equipped page teleprinter produces telegrams of uniform size with conventional headings. Unit at right assures correct message number, paper registration

equipped page printers to branch offices and tributaries and for private wire services involves other problems, but keyboard standardization and the basic development of applying page printers to Western Union internal operations have been completed and plans for exploitation are well under way.

Robert W. Harris, Assistant to the Systems lanning Engineer, is a graduate of the Columbia Uni-ersity School of Mines, Engineering and Chemistry where received the degree of Mechanical Engineer. During orld War I he served in the Air Service, Signal Corps, a pursuit pilot. He joined the staff of the Traffic Engineer 1921, and subsequently moved to the Systems Develop-ent Division of the Development and Research Depart-ent. Mr. Harris has long been active in studies of improved legraph methods and services extending over a broad field f interest, where correlation of research and development ith operating requirements has been a prime requisite. lore recently, the Keyboard Standardization project is one which he has played a major part.

DVORAK'S TYPEWRITER KEYBOARD LAYOUT REVIVED



Over 20 years ago Western Union examined a typewriter keyboard layout arranged by Comdr. August Dvorak, USN, to improve distribution of work load between the right and left hands and among the various fingers.

Navy Department tests of the Dvorak keyboard were publicized in 1945 and new tests proposed by the Government's General Services Administration received considerable newspaper notice recently.

Although previous tests showed marked increases in typing efficiency and accuracy, it generally was considered impractical to retrain operators and rebuild machines.

Patents Recently Issued to Western Union

Facsimile Transceivers

R. J. Wise, G. H. Ridings, R. D. Parrott
2,718,547—September 20, 1955

Mechanism for a facsimile transceiver of the type now generally known as the optical. Principal Desk-Fax features are a one-piece cast chassis, a scanning and recording drum slidable along the driving shaft under control of a rack-driven carriage having spring return, a jointed stylus arm movable forward by means of a motor which stalls when the stylus contacts the drum and is retracted by a spring at end of message upon deenergization of the motor. Four separate motors, respectively, drive the drum, carriage, light chopper and position the stylus. The machine is conditioned for sending or receiving by interlocking Send and Receive push buttons and is released by a Stop button.

Variable Blanking for Facsimile Transmitter

C. Jelinek, Jr.
2,718,548—September 20, 1955

To effect blanking during the underlap or other period during rotation of a drum-type transmitter, two adjacent cams rotate with the shaft, one fixed to coincide with the leading edge of the copy and the other adjustable to define the trailing edge. Cooperating raised portions of the cams hold a blanking switch open during the length of the copy while coincident lowered cam sectors allow the switch to close during the underlap period. To effect blanking, the switch may short-circuit the transmitter output or, in the case of negative copy, may switch the line to a separate oscillator to provide a positive blanking signal.

Stylus Scanning Devices for Facsimile Machines

D. M. Zabriskie
2,723,897—November 15, 1955

A stylus assembly intended particularly for belt-type facsimile recorders, comprising a metal cylinder for attachment to the stylus belt and enclosing a piston of nylon or other insulating material with the stylus fixed in an axial bore therein. A coil spring fixed between the piston and the closed rear end of the cylinder exerts forward pressure to maintain uniform stylus contact with the recording paper. Surrounding the cylinder is an eccentric collar adapted to slide along a guiding bar during recording and which may be rotated to align the styli with respect to each other.

Method and Apparatus for Generating Facsimile Signals

R. J. Wise
2,721,231—October 18, 1955

In a facsimile phasing and blanking arrangement, phasing carrier pulses are first sent to line under control of a separate photocell which scans the gap between the trailing and leading edges of the message blank either through a transparent drum or by reflected light. After the phasing interval, the same pulses serve to interrupt the picture carrier during the gap to effect blanking. As illustrated, the pulses key the phasing carrier and later the signal carrier by bias control of balanced diodes interposed in the respective paths.

Photoelectric Tape Reader

W. S. W. Edgar, Jr.
2,724,014—November 15, 1955

An arrangement for sensing perforated tape comprising a light source of small area, a shutter and a series of apertures in register with the tape holes all beneath the tape, and a series of photocells located in an arc, or otherwise, above the tape and adapted, respectively, to intercept the cones of light traversing the tape holes. The photocells may operate thyratrons which are extinguished after each character scan by interruption of the common anode supply following operation of the shutter and tape advance. The reader assembly employs no lenses or reflectors and is adapted for convenient bracket mounting to standard reperforators.